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***All correspondence relating to the publication of papers* should be addressed to**

Harry E. Jordan, Secretary
500 Fifth Avenue, New York 18, N. Y.

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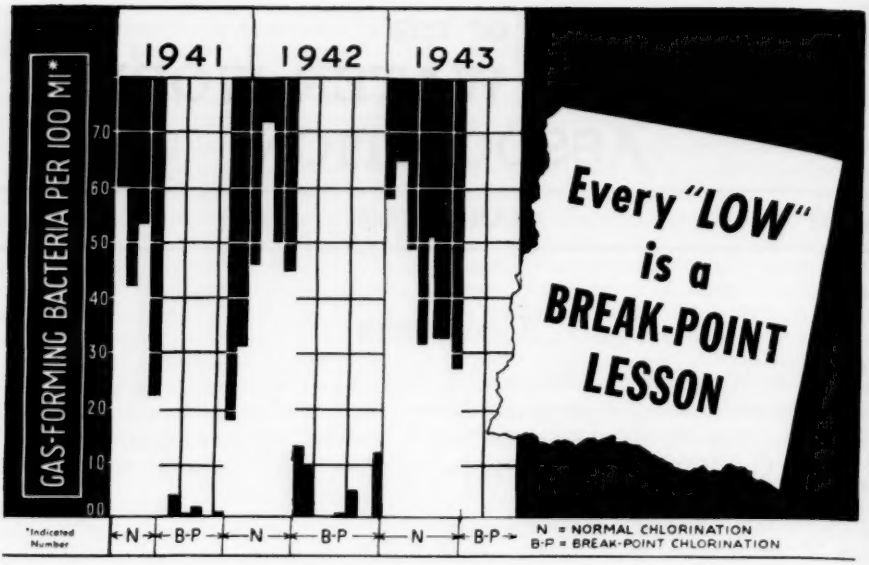

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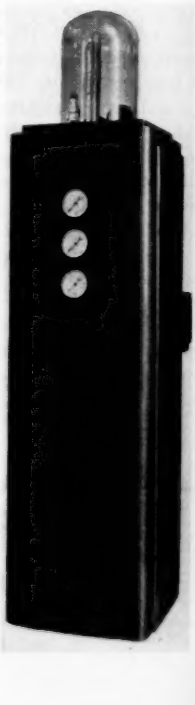

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Vol. 38 March 1946 No. 3

Water Works Intakes

By Charles B. Burdick

Alvord, Burdick & Howson, Engrs., Chicago, Ill.

Presented on Nov. 15, 1945, at the Wisconsin Section Meeting, Milwaukee, Wis.

GOOD water is worth whatever it costs. Large expenditures are often made to bring it from great distances. It is not generally recognized that, even when the supply lies at the doorstep of the city, considerable ingenuity and important expenditures may be required to insure a continuous supply to the pumps. Perhaps an extreme case is the city of Chicago, which is located on the shore of Lake Michigan and where about 20 per cent of the total investment in water works has been necessarily expended for the cribs and tunnels which take the water from the lake and deliver it to the pumping stations.

One would naturally think that a pipe dropped into a body of fresh water 3 or 4 ft. below the surface would be all that is required. In service reservoirs and in some small sheltered lakes this *is* all that is necessary. In fact, such a pipe would be sufficient on any lake or stream a great percentage of the time. It is the city water works' requirement of continuous service, even under adverse conditions seldom occurring, that justifies the special constructions adapted to fit a variety of conditions. Among these conditions is the necessity for:

1. Protection against wave action and floods to insure permanency.
2. Protection against the action of ice to prevent stoppage and to exclude floating objects.
3. Protection against the ingress of sand, which may be destructive to pumps and valves.
4. Protection against pollution, as far as this can be done, by choice of location of the intake and depth at which the water is taken.
5. The nature of the construction is also governed by the amount of water to be taken.

The author's purpose here is to describe the different types of intakes that have proved most efficient in the

various circumstances under which public water supplies are taken.

Intakes on Great Lakes

The Great Lakes from Superior to Ontario constitute the largest body of good drinking water to be found anywhere. Nearly all of this water is crystal clear and pure. It is natural to think that under such conditions good water could be easily and cheaply obtained. While, relatively speaking, this is so, as compared to the interior of the United States, the size of these bodies of water and the condition of their bottoms and shores within reasonable reach of the cities make it difficult to obtain a continuous supply because of ice and sand and the turbulence of the waters during storms.

The Great Lakes were formed by the erosion of the glaciers. Their beds were scooped out by the ice and nearly everywhere the bottom consists of blue clay with a fringe of sand extending outward from the shore only a few miles. At the foot of Lake Michigan, where large supplies of lake water are developed, the underlying limestone lies about 100 ft. below lake level and is overlaid by about 50 ft. of blue clay and 50 ft. of fine sand. To the northward, especially along the west shore, the sand thins out and the clay approaches lake level. In a few isolated places the limestone outcrops reach an elevation above lake level. The surface washings brought in by the tributary streams are quickly settled out and, while such impurities are dissipated by the great dilution, the accumulations are sufficient to create lake turbidities of considerable amount when churned up by the waves of a strong off-shore wind. Turbidities exceeding 100 ppm. occur yearly as much as two or three miles from shore.

The turbulence of the lakes prevents the formation of heavy ice except close to the shores and in the narrow places in the straits from lake to lake. Occasionally in calm, cold weather a sheet of ice will form outward several miles from shore and may remain for a matter of weeks. Under certain conditions of wind these ice sheets are more or less broken up and driven to the shore, often with considerable violence. These ice floes strand in the shallow water and, as other ice is forced shoreward, the ice is piled up to considerable height, augmented by the breaking of the waves and additional freezing in a protracted period of cold weather. Thus, from accretions on top and the sinking due to additional weight, ice may become nearly solid from top to bottom of the lake 500 to 1,000 ft. from shore in water 10 to 12 ft. deep. It is reported that ice jams against the Chicago cribs have piled the ice from 10 to 25 ft. high and down to the bottom of the lake. Under such conditions it becomes impracticable to take large quantities of water for public water works near the shore line with any assurance of a continuous supply. For these and other reasons, the city water works necessarily takes its supply at a considerable distance from shore.

Chicago Intakes

At the present time the Chicago Water Works obtains its supply from six surface cribs varying in distance from two to three miles from shore. These are circular structures, which vary from 90 to 112 ft. in diameter and are located in water from 32 to 37 ft. deep at the various cribs. Water is taken in through ports in the sides of the structure, which generally extend from 5 to 12 ft. above lake bed, and enters a circular well in the center of the crib

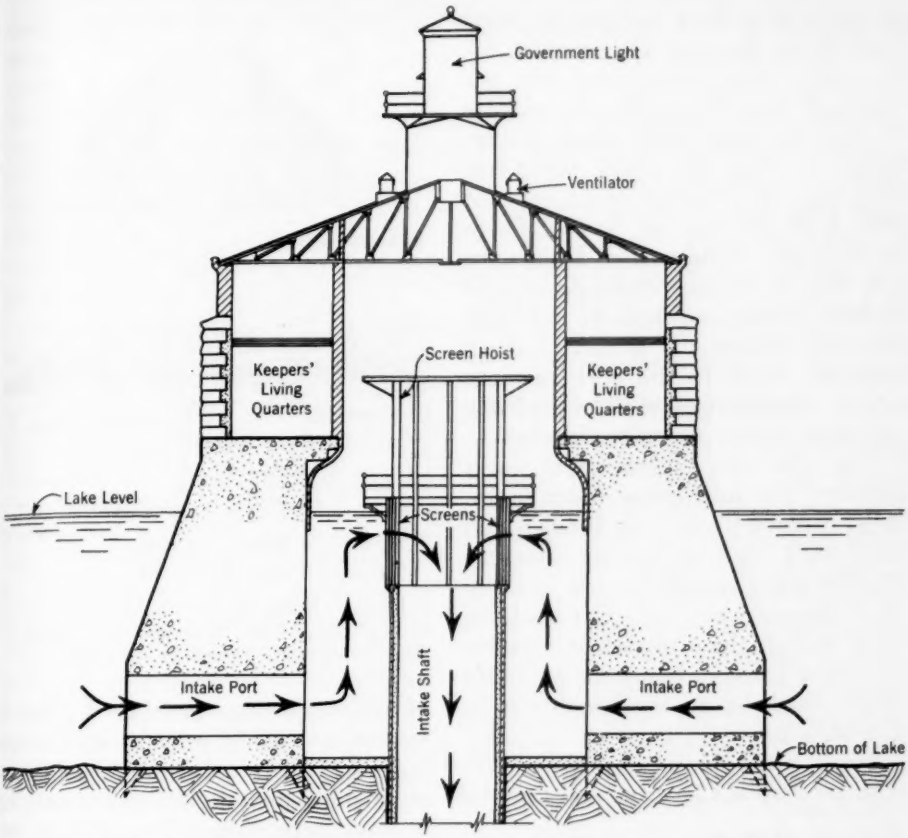

FIG. 1. Typical Chicago Intake Crib, Showing Method of Taking Large Supplies of Water From Lake Michigan at Depths of 32 to 37 ft.

from which a shaft extends downward to a connection with a tunnel extending inland to one or more of the city pumping stations. The water is controlled as it enters this downtake shaft. The ports at the outer circumference of the crib are proportioned to a maximum delivery of about 1 fps. and the draft per crib often exceeds 400 mgd.

Figure 1 illustrates a typical Chicago intake.

A structure on the above dimensions, in a locality subject to navigation and in the relatively shallow depths of water prevailing, necessarily extends above the surface of the lake. The parapet walls of the Chicago cribs are about 27 ft. above the ordinary low water level in order to provide for the fluctuations in lake level and the action of the waves. The surface of Lake Michigan at Chicago is constantly changing with the direction of the wind and varies over long periods with the variations in rainfall. Although the annual average level varies from about 1 ft. below datum to 2 ft. above datum, extremes may vary as much as from -4 to $+6$.

The Chicago cribs are necessarily maintained as lighthouses and, as their continuous operation in winter requires

an ice-fighting force to keep the ports open, living quarters are provided for permanent attendants. The cribs are equipped with boilers for the purpose of supplying pumps and steam jets required to keep the intake ports free from ice. Ice trouble is caused not only from floating ice forced downward as the ice floes drive against the crib but, in certain conditions of cold weather, needle and slush ice is formed near the surface and is carried down with the water to the port openings where it lodges and would completely stop them unless manually dislodged.

The cribs are constructed of heavy masonry, the part below water necessarily contained within an annular steel plate shell sunk on cutting shoes so that the edges penetrate a few feet into the comparatively soft clay bottom. Even though these masses of concrete and stone are very heavy, they tremble when struck by an ice floe driven by a brisk wind.

Intake cribs similar to those at Chicago are used at Cleveland and Buffalo.

Submerged Cribs

Where conditions are favorable, particularly as to water depths available, cribs entirely submerged are practicable even for large supplies and are almost universally used in supplying smaller Great Lakes cities. The intake crib at Gary, Ind., is a successful example of the submerged crib for large water delivery (Fig. 2).

The Gary crib is located at the southern end of Lake Michigan and one and one-half miles from shore in water about 44 ft. deep. The crib is octagonal in shape, 60 ft. inside diameter and 10 ft. in height. It has a solid bottom consisting of two layers of 12 × 12 timbers on which is superimposed a cellular crib work of timbers

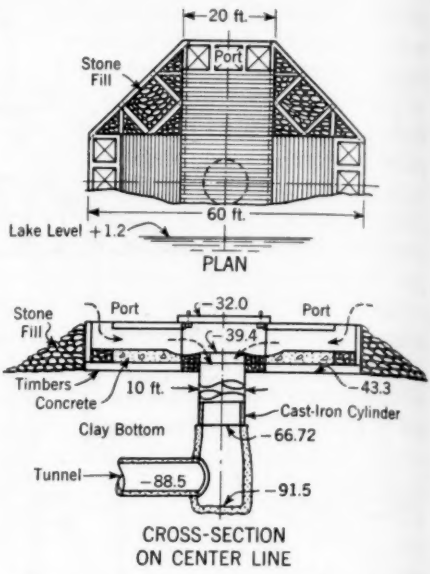

FIG. 2. Submerged Crib in Lake Michigan at Gary, Ind., Adaptable to Conditions Where Adequate Depth Is Available

of the same size, built up log-house fashion and solidly joined with through bolts and drift bolts, stone and concrete filled and decked over with 12 × 12 timbers. The crib rests upon the clay lake bottom with no other support than a thin layer of crushed stone to level up the bottom, and is surrounded by an embankment of heavy riprap stones, 26 ft. wide on the bottom, and sloping upward to the top of the crib. The water enters at twelve 5 × 5-ft. ports lying in the horizontal plane of the top at the outer edges of the crib, from whence it passes to a central well extending downward to a tunnel in the clay located about 45 ft. below lake bottom.

The depth of water at this crib apparently prevents a noticeable movement of sand due to wave action. There is only a trace of sand on clay bottom at the site. What is regarded as an essential feature of such a sub-

merged crib is the low velocity of the water at the intake ports and the separation of the ports so as to minimize lake velocities. This crib was designed to take 60 mgd. at an intake port velocity of $\frac{1}{3}$ fps. The crib has been in successful use since 1909 and there have been no ice or sand troubles. The maximum delivery up to the present time has been about 35 mgd.

In the construction of the Gary crib and tunnel, the crib was built on shore, launched, floated to the site and sunk by the addition of the necessary weight in stone and concrete. In the process of sinking, it was built up as it sank by the addition of a temporary crib framework lashed to the permanent crib, also filled with stone in the process of sinking. This structure was built with a central well and extended above the water line. A cast-iron cylinder, 10 ft. in diameter in short sections and with a cutting edge on the lower section, was then lowered into the central well and forced into the underlying clay bottom by heavily loading the top of the cylinder and excavating on the inside with a clamshell bucket until a sufficient depth of clay had been penetrated to permit it to be pumped out. The shaft was then extended and lined progressively downward; the tunnel eye was formed and the tunnel extended to about 20 ft. inland, where a strong bulkhead was built containing a short pipe and valve. A blind flange, also containing a valve, was then bolted on the cast-iron cylinder inside the crib just above its bottom. Then the temporary crib superstructure was unlashed by the aid of divers, and floated away by the removal of the stone filling. The intake tunnel, which meanwhile had been under construction, extending outward from shore, met the short tunnel extension near the foot of the downtake shaft. The valve in the previously mentioned bulkhead was opened, no water was found in the shaft and the bulkhead was torn away. The shaft and the tunnel were then filled by opening the valve in the blind flange at the top of the intake shaft. The blind flange was then taken off and the cover of 12 × 12 timbers was permanently set at the crib top level over the central well of the crib. The structure was then ready for use.

Milwaukee Submerged Crib

The city of Milwaukee is now served through the Linwood Avenue intake, which is supplied through a submerged crib 6,565 ft. from shore in water 67 ft. deep. The water from the crib is taken through a 12-ft. rock tunnel 81 ft. below lake level. At the shore end of this tunnel, water is taken by low-lift pumps which supply the filtration plant, after which the filtered water is returned to the tunnel system which supplies the two city pumping stations.

The intake crib has a form essentially similar to the Gary crib described above except that the dimensions are slightly greater. The crib is 80 ft. in diameter and 12 ft. in height. It has an estimated capacity of from 220 to 368 mgd. and intake port velocities similar to the Gary crib. This crib has been in successful operation since 1918 without experiencing any difficulties. Milwaukee has another lake intake located at the North Point pumping station, which is no longer used but is held in reserve for emergencies.

Other Submerged Intakes

Practically all the smaller cities on the Great Lakes are supplied through submerged intakes.

The intake at Racine is similar to the Gary intake but of smaller dimensions,

corresponding to a smaller pumpage at Racine. It is 33 ft. 4 in. in diameter, 8 ft. in height and rests upon lake bottom in 37 ft. of water. Water is carried from the intake to shore in a 36-in. pipe laid just below the floor of the lake.

A still smaller supply at Glencoe, Ill., is furnished through a pipe intake in which no crib is used. Water is taken in through a 24-in. intake pipe laid below the bed of Lake Michigan, terminating in six upturned tees, elbows and increasers so proportioned as to maintain an inlet velocity of about ¼ fps. This intake serves about 6,000 people. It is located 3,300 ft. from shore. The intake openings lie in a horizontal plane 4 ft. above the bottom of Lake Michigan in water about 23 ft. deep.

It is believed that the essentials for success include low intake velocity and symmetry with reference to the intake openings. In some intakes, where the inlet openings have been distributed along the intake pipe, greater trouble has been noted from stoppages caused by anchor ice, possibly due to greater velocities in the openings nearest to shore. It also seems to be desirable with the larger quantities of water to spread the intake ports so that too much water is not drawn at one spot.

River Intakes

When water is drawn from a river some of the problems applicable to the lake intakes are not present but there is difficulty caused by greater variations in water depth, in some cases by heavy drift and particularly by the character of the river bottom.

Some of the earliest water works in the West were built upon the Ohio and Mississippi rivers. On the Ohio River the difference between low water and high water is as much as 50 to 80 ft. The intake structures upon these early plants are somewhat similar to the tower intakes commonly used in the East to take water from impounding reservoirs, where water may be taken at more than one elevation.

The intake at the Cincinnati Water Works, completed about 1906, is located near the Kentucky bank of the river and supplies the water works on the Ohio side through a 7-ft. rock tunnel. The intake structure has the general appearance of a tall bridge pier. It is 55 ft. by 27 ft. in plan at the foundation line, extends 80 ft. above low water and rests upon solid rock about 40 ft. below low water. It is built of stone masonry resting upon a timber caisson sunk through a heavy bed of gravel which overlies rock. Water is admitted through six ports, of 24 sq.ft. each, so arranged as to have some selection in the depth at which the water is taken. The velocity is quite moderate if all ports are open, being only about ⅛ fps. under the pumpage rates that prevailed at the time the works were built. Each port, however, is provided with a screen of ¼-in. mesh and much trouble was experienced in the early use of the intake to keep these screens clear. Six men are understood to have been necessary for this purpose.

New Albany Intake

This is a case where water is taken on the rapids of the Ohio River. At this place the river runs on a rock bottom with a minimum depth of about 3 ft. at low water. It is necessary here that the intake structure should not extend materially above the bottom of the river for the location of the intake is in the path of river navigation at the higher stages of water. Here the intake pipe and intake are laid in a rock

trench. The intake structure is built of steel plates, set in the excavated trench and backfilled on the outside with concrete. The intake is so formed that openings face downstream to minimize the entrance of floating objects. In this case the intake port is protected by a coarse bar screen to exclude large objects.

Intake on Soft Bottom

The intake for the city water supply at Terre Haute, Ind., is in general similar to the intake previously described at New Albany. At Terre Haute, however, the river bottom is very soft and consists of mud and fine sand which are periodically washed out and replaced with the rise and fall of the flood waters.

The intake box at Terre Haute is supported on piles by means of steel brackets on the side of the box. The pipe leading from this intake to shore is also carried on piles.

Perforated Pipes

There is another type of intake which has been extensively used, particularly on rivers of good velocity and reasonably permanent bottoms. The intake at the Williams Creek pumping station, Knoxville, Tenn., consists of two 36-in. pipes extending 75 ft. outward from the shore line in water about 10 ft. deep at low water stage. The tops of the pipes are submerged 5½ ft. The three outer 12 ft. lengths of each intake line are perforated with a large number of 1-in. holes of such aggregate area that the maximum intake velocity is substantially ¼ fps.

These intake pipes are located at a point where the Tennessee River has a relatively permanent cross-section. The supporting piers extend well into the hardpan bottom so that the probability of undercutting is avoided.

The sizes of the perforations in the pipe are so proportioned as to exclude the larger floating objects. Small floating objects easily pass through the centrifugal low-lift pumps and are removed in the settling basins of the filtration plant. For a few weeks at the time of falling leaves some trouble is experienced from the stoppage of the holes in the intake pipes. This is easily overcome by backflushing.

The Evansville, Ind., water works has a similar perforated pipe intake, consisting of three 36-in. pipes extending into deep water a short distance from shore. In this case the river has a relatively soft bottom and the intake pipes are supported on piles. Evansville has successfully used this intake for about 45 years. Recently it was cleaned by interior scraping. This was found necessary because of tuberculation in the pipes which plugged up many of the holes and reduced the carrying capacity of the pipe.

Unstable Bottoms

There are some rivers that pick up their beds to considerable depths during great floods. This is particularly true of rivers in the Southwest, like the Rio Grande, where the raw water turbidities recorded have reached 35,000 ppm. It would be impracticable to maintain an intake or an intake pipe on the bed of such a river and it would probably be undesirable because of the heavy concentration of sand and mud flow near the ordinary river bottom.

On rivers such as these it is necessary to provide an intake structure at or near the shore and it is desirable that it should be constructed so that the bars or mud banks which may be formed in front of the intake can be

cleaned away periodically and a clear channel maintained as the river subsides.

The intake and suction well constructed at Laredo, Tex., on the Rio Grande illustrate the kind of construction that is sometimes necessary to take water from rivers with unstable bottoms (see Fig. 3). On the Rio Grande ice troubles are not present.

Inclines

The subject of intakes would not be complete without describing the movable river bank intakes used at several places upon the Ohio and Missouri rivers, particularly in small water works but in some larger plants. At the Missouri River plant of the St. Louis County Water Co., four pumps, with an aggregate capacity of 54 mgd., are accommodated upon steeply inclined steel rails, extending from the top of the bank to low water, a vertical height of about 35 ft. Each pump, as well as its small house covering and its short length of suction pipe with a suitable screen on the inlet, is carried on a truck moved up and down the bank. The pumps discharge through temporary connections to an inclined discharge pipe. The discharge pipe connection is changed from time to time in accordance with the comparatively slow change in the elevation of the Missouri River. This type of intake is particularly indicated because of the shifting bottom and banks of the Missouri River during floods. Considerable expense has been required for bank protection adjacent to this group of pumps in order to provide reasonable permanence. This type of intake was resorted to because of the difficulty of maintaining a former intake structure in the river bed, with its heavy deposits of sand and gravel.

Lake Shore Intakes

The comparatively large expenditures required on the Great Lakes for off-shore crib and tunnel intakes for large quantities of water have led to numerous attempts to obtain water at the shore line for power plants or manufacturing institutions, where the quality of water is of secondary consideration. Comparatively simple construction would be sufficient to furnish even large supplies the greater part of the time. Supplies of absolute continuity can be obtained only with considerable difficulty. Some of the experiences in connection with the development of shore water in the Chicago region are instructive.

The large power generating stations in Chicago obtain Lake Michigan con-

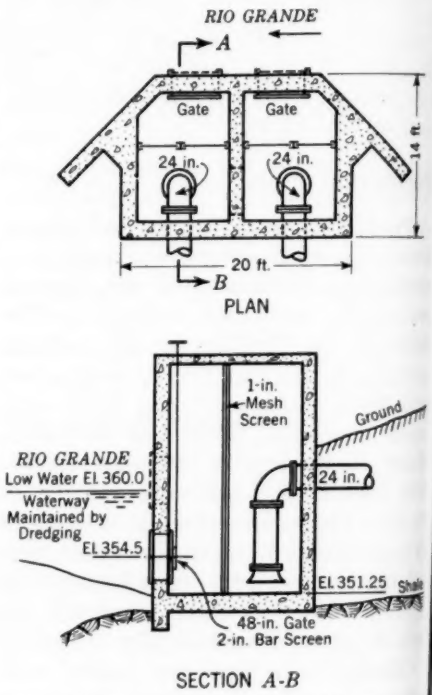

FIG. 3. River Intake at Laredo, Tex., on Rio Grande, Located on Shore Because of Unstable Conditions in River Bed

densing water but draw it from the Chicago River and the North Shore channel or take a mixture of Lake Michigan water and land water from the Calumet River about half a mile above its junction with Lake Michigan. In all three of these cases the intakes are essentially river intakes located at the dock line. As these streams where the water is taken are essentially sluggish rivers, no important trouble is experienced from floating ice or anchor ice. Conditions are essentially the same in the case of the large steel industries in the Gary region, where extensive drafts are likewise made from the navigation slips which, through periodic dredging, maintain ample depths of quiet water with the exclusion of the storm action and the driving ice that is experienced directly on the lake shore.

There have been several attempts to take large drafts of water at the lake shore line behind protective breakwaters. So far as is known they have not been permanently successful although they are capable of furnishing large supplies the great majority of the time. A case in point is the experience of the 39th Street pumping station of the Chicago Sanitary District, which for many years drew a large volume of lake water at the shore line and discharged it into the south branch of the Chicago River for the purpose of maintaining sanitary conditions therein. Two 1,000-cfs. pumps were installed in this station. The water was drawn from a breakwater enclosure or forebay about 150 × 200 ft. in plan, consisting of piles, timber crib and stone fill. The opening to this enclosure was on the southwestern side so that the driving action of ice and heavy waves, which principally occur with northeasterly winds, was obviated. Depths of from 12 to 15 ft. were maintained in the forebay. It was necessary to dredge the enclosure at intervals of from three to five years.

While in general sufficient water could be obtained, there were one or two occasions in a five-year period when the ice so clogged the forebay openings as seriously to endanger the structure. At such times the pumps were shut down, as the continuity of dilution water was not considered a very important matter.

On the North Shore channel of the Chicago Sanitary District dilution water is pumped from Lake Michigan. Four pumps of 250-cfs. capacity each have been in service when required since 1910. Formerly one or two pumps ran fairly steadily. The pumps are located several hundred feet inland and take water from racked openings somewhat similar to the intake of a low-head water power plant.

Trouble at this station comes when wind and lake level changes break up the ice sheet on the lake, crowd the ice cakes into the channel and against the racks of the pump intakes. Serious trouble has also been experienced from the growth of grass which at times stops up the racks. In the course of years the intake connection to the lake has become badly sanded up.

There are several cases where large power generating stations have maintained their supplies of condensing water at the Lake Michigan shore line. These stations solve the sand problem by protective breakwaters and periodic dredging. They solve the ice troubles by turning the warmed condensing water into the cold water intake during the comparatively short periods when the ice is driving in or when anchor ice is forming.

The Chicago South Side filter plant, now under construction and operating at present as a sedimentation plant, is so constructed that it can and is taking water directly from the lake into the pump suction wells at a point which is about 1,500 ft. from the natural shore line and where the water is about 21 ft. deep. The only protection for the inlet openings is a breakwater about 800 ft. outward, which serves to minimize driving sand and ice in storms. It is expected that dredging to remove sand in front of the suction well gates will be required periodically. No doubt this intake will be operative the great majority of the time, but to guard against the rare occurrence of heavy drifting ice floes a connection is being provided to the existing tunnel from the present 68th Street and Dunn cribs about 4,500 ft. north of the filter plant. Water is supplied directly from the lake to the suction well through 25 ports with an aggregate area of 1,806 sq.ft., thus making possible a velocity of about 0.3 fps. at the present proposed capacity of the filter plant.

Screens

Where water is not subsequently filtered, it is very desirable to exclude fish or floating objects.

At the Chicago lake cribs, screens of $\frac{1}{2}$-in. mesh are contained in the water passages between the central intake well and the downtake shaft to the tunnels at velocities exceeding 1 fps. In winter, during the ice season, it has been found impracticable to keep these screens in operation and they are removed when necessary. However, additional screens of larger area are installed inland at the pumping stations.

In the case of submerged intakes, it is not practical to locate screens at the inlets for there would be no way to clean them. In many cases on the Great Lakes and also on the rivers, the intake pipe leads into a suction well at the pumping station. In these cases, the suction well offers an excellent opportunity for screening at low velocities and under circumstances in which the screen can be removed and cleaned. At the Gary Water Works, the screens are in the form of a cylindrical cage surrounding the 10-ft. uptake shaft from tunnel to suction well. This permits very slow velocities and makes it possible to handle the vertical sliding screens by means of the pump room traveling crane. The Gary screens are $\frac{3}{8}$-in. mesh.

Perforated intake pipes which serve the purpose of screens have previously been mentioned. Many of the rivers at times of flood carry considerable drift which should be excluded from conduits and pumps. A relatively coarse grating at the point of intake and a somewhat finer screen at a suitable well at the pumping station serve very well. Where the water is subsequently filtered, screens of 1-in. openings are usually sufficient. Bar screens similar to those used in water power plants are effective and most easily cleaned.

In the pumping of large quantities of water, manual attendance at screens may become a serious burden and expense. The larger water works plants are following generating station condenser experience by installing mechanically operated screens, which are automatically cleaned, and water under pressure, which is automatically controlled if desired.

At Louisville, Ky., where the intake structure is similar to that at Cincinnati and built about the same time, much less trouble has been experienced with screens. At Louisville, the

screens are so arranged within the interior well of the intake that they furnish a much larger area in proportion to the volume of water taken. Double screens were provided, so arranged that they can be raised for cleaning without entirely stopping the operation of screening. Even so, large objects have occasionally passed the double screens during cleaning operations. This resulted a few years ago in the installation of traveling screens which are automatically cleaned. The traveling screens have an opening of $\frac{1}{2}$ in. and the velocity based on the gross low water area of the screen at normal rates of pumpage is approximately $\frac{1}{3}$ fps. This velocity is reduced one half with two screens in operation and is further decreased through increased screen area in floods. A large part of the time the screens remain in place without motion. It is only when considerable drift is flowing, as during floods or at certain seasons of the year when fish are particularly numerous, that it is found necessary to set the screens in motion. Continuous operation is not necessary even at such times, although the motors may be run for a short time several times a day.

At the Chicago South Side filter plant, manually operated screens are installed in the pump suction well passages where relatively slow velocities are possible.

Additions to Miami Water Supply System

By C. F. Wertz

Resident Engr., Dept. of Water & Sewers, Miami, Fla.

Presented on Nov. 15, 1945, at the Florida Section Meeting, Miami Beach, Fla.

THE demand for water in the metropolitan district of Miami has grown at a rate equaled by few cities in this country. A water softening plant built in 1925, with a capacity of 10 mgd., had its capacity doubled in 1927, quadrupled in 1936 to its present size of 40 mgd. and in 1946 will be sextupled to 60 mgd. Predictions from population and demand curves indicate that this new capacity will again have to be increased in 1955.

A pertinent question at this time would be, "Why not design for more capacity?" The answer to that question is that the hydraulic problem of trying to pass 60 mgd. through a plant originally designed for 10 mgd. and now handling 40 mgd., only by bypassing approximately 10 mgd. around the recarbonating basin, was one not easily solved. In order to keep losses through the plant down to a minimum, the new sluice gates, 24 in number, will be extremely large—some of them as large as 6 ft. by 7 ft.

All of the improvements about to be discussed have been made since the acquisition of the Miami Water Company by the city and the establishment of the present Department of Water and Sewers in April 1941.

The first major improvement was the construction of a new 42-in. cast-iron transmission main from the water softening plant in Hialeah to the north side of the city. In 1942, 26,000 ft. of 42-in. line and 10,000 ft. of 30-in. line were laid at a cost of $560,000. At that time, the War Production Board would not give the department a priority for pumps to deliver water through this main, so an old 16-in. pump, which had been retired in January 1939, was reset in November 1943 and is today pumping at a rate of approximately 15 mgd.

The second improvement (begun in 1944 and completed this year) was the construction of a 2.5-mil.gal. storage tank; a pumping station with an ultimate capacity of 25 mil.gal. but now containing only one 6-mil.gal. pump; and a high-pressure line of 30-in. cast-iron pipe, approximately 6,600 ft. long; all at a total cost of $230,000. The pumping station is at the end of the 42-in. transmission main, mentioned above, at N.W. 67th Avenue and 10th Street. Of special interest is the storage tank, which is a wire-prestressed, concrete tank, 144 ft. in diameter, with a self-supporting dome (Fig. 1). Approximately 80 miles of high-tensile-strength wire was used as horizontal reinforcing in this tank.

A later project, recently completed, extended the 30-in. high-pressure line an additional 10,700 ft. to a connection at the western terminus of the North Bay (79th Street) Causeway with a 30-in. cast-iron line recently con-

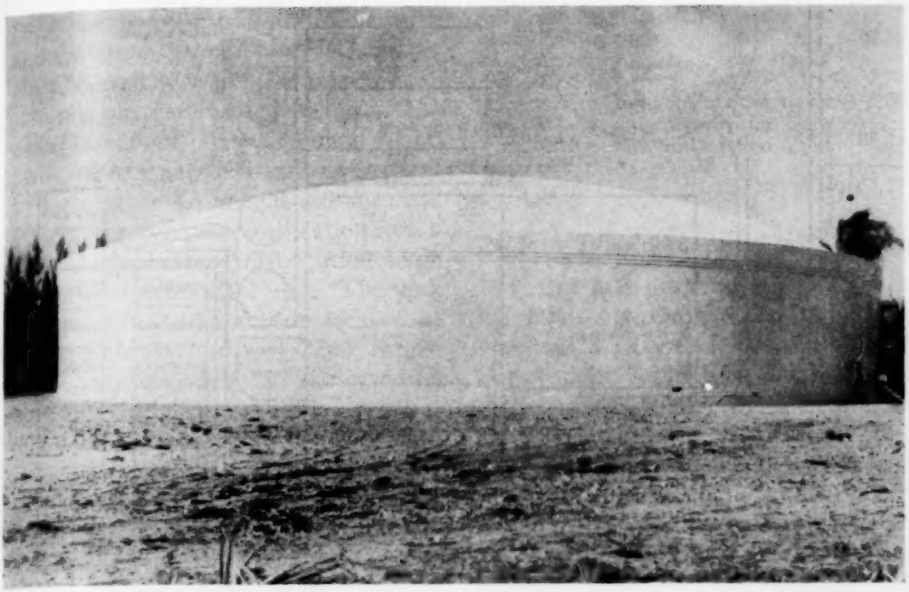

FIG. 1. Wire-Prestressed, Concrete Storage Tank—2.5-mil.gal. Capacity—Miami, Fla.

structed across the causeway by the city of Miami Beach. This 30-in. extension cost $212,000.

All of the pipe in the above projects (53,300 ft.) was laid with sulfur compound joints.

Plans for the improvement and enlargement of the water softening plant (see Figs. 2 and 3) were started about July 1944. The first contract, to acquire additional raw water for the plant, was let January 1945, and was completed in December. This project included five new 14-in. wells, averaging 92 ft. in depth; five new well pumping stations; and raw water collection and transmission mains to the softening plant.

The mains consist of 500 ft. of 18-in. pipe, 1,600 ft. of 24-in. pipe, 2,250 ft. of 30-in. pipe, 2,350 ft. of 48-in. pipe and 1,300 ft. of 60-in. pipe, all cast iron. The project also includes two 30-in. cast-iron, mechanical joint river crossings. The small amount of 60-in. cast-iron pipe—the largest diameter water pipe in Florida—is not needed for the present flow, but it is part of a future plan to bring all raw water from a new well field located some six miles west of the softening plant. The future plan also calls for two additional 30-in. diameter river crossings. The cost of the above project will be about $222,000.

Lead joints were poured on the 48- and 60-in. diameter lines, and a sulfur compound was used on the smaller lines.

Plans are about 90 per cent complete, and contracts for the pipe and fittings for a new cast-iron transmission main from the softening plant to the downtown high-pressure pumping stations are already let. The line will consist of approximately 19,350 ft. of 42-in. pipe and 9,000 ft. of 36-in. pipe. It will replace two existing wood-stave

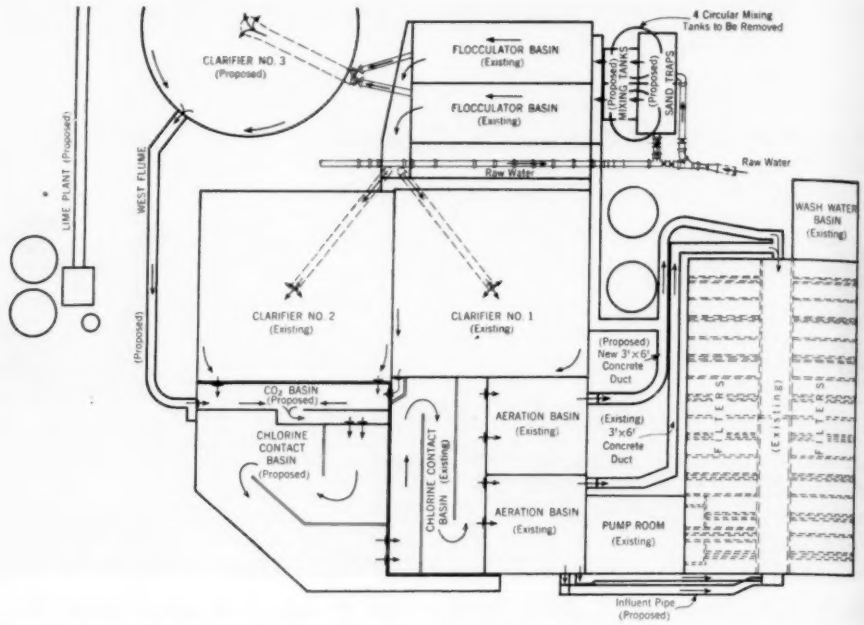

FIG. 2. General Plan of Water Softening Plant, Showing Existing and Proposed Structures —Miami, Fla.

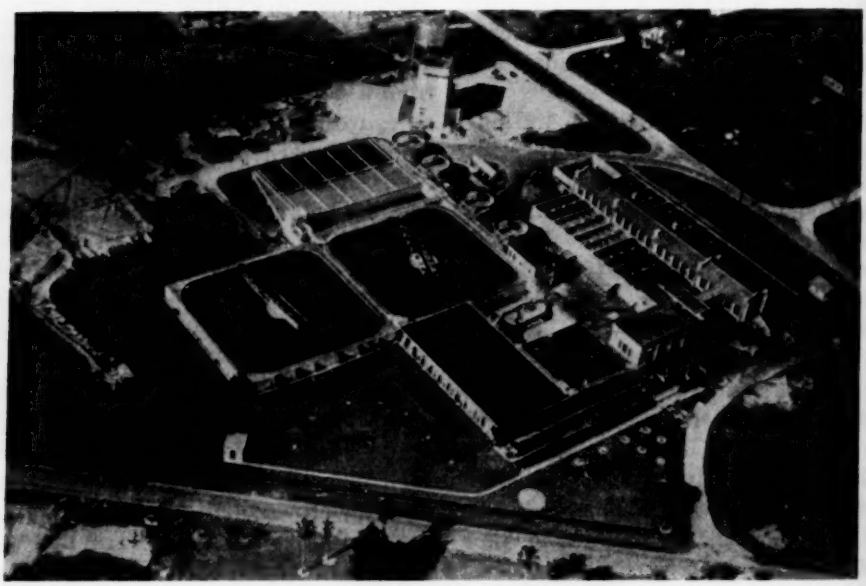

FIG. 3. Air View of Existing 40-mgd. Water Softening Plant—Miami, Fla.

lines, one of which is 36 in. in diameter and the other 30 in. The 1945 budget has allocated $780,000 for this line.

While plans were progressing for the enlargement of the softening plant, plans were completed and a contract let for another 2.5-mil.gal. storage tank, a high-pressure pumping station and a 30-in. high-pressure distribution main on the west side of the city. The tank and pumping station are located at N.W. 30th Avenue and 22nd Street, where the existing 36-in. cast-iron transmission line going to the incinerator pumping station will be tapped. Later the pumping station will be supplied by the new 42-in. cast-iron line, which will replace the present 36-in. wood-stave transmission main. The 30-in. distribution main, 10,500 ft. in length, will connect to an existing 24-in. main at West Flagler Street and 27th Avenue. The pumping station will improve pressures in the Coconut Grove section of Miami and in the city of Coral Gables. The tank will be a wire-prestressed, concrete type similar to the N.W. 67th Street tank. The project is now under construction and it is estimated that it will cost $358,000.

Plans for the softening plant enlargement had progressed to a point where, on July 9, 1945, it was deemed advisable to advertise for bids on most of the major equipment items so that tardy delivery dates would not delay the contractor when a construction contract was let. In August 1945 contracts were let for the following:

One clarifier mechanism	$ 12,250
One Venturi meter, two new registers and a summator	3,300
24 electrically operated sluice gates	53,000
230 tons of cast-iron pipe and fittings	18,750
Three 3,000-lb. chlorinators and auxiliary equipment	21,530
Two mixing tank mechanisms	4,500
Four sludge pumps	1,800
Automatic remote control system for well field pumps	25,800
48- and 42-in. valves, electrically operated	9,700
pH recording and control equipment	2,200
Two 5000-lb. gravimetric lime feeders, with pumps and suction tanks	14,440
TOTAL	$167,270

Present Treatment

To the raw water in four steel mixing tanks approximately 170 ppm. of lime and 8.5 ppm. of alum are added. Some slight aeration is obtained over mixing tank influent weirs before the chemicals are added. Beyond the mixing tanks the water passes through Dorr flocculators, is treated with ammonia and chlorine, then enters two Dorr Si-feed clarifiers. The clarifier effluent, which has an average turbidity of from 3 to 4 ppm., passes through a final settling basin and a recarbonating basin before reaching the filters, which are sixteen in number. Water entering the plant with an average hardness of 260 ppm. and a color of 70 ppm. leaves the plant with an average hardness of 80 ppm. and a color of 24 ppm.

In 1942 it was decided to try to find, by actual pilot plant experimentation, a method by which color could be further reduced at a reasonable cost. A scale model of the main plant was built to operate at 10 gpm., and for the ensuing two years tests covering two dozen or more types of chemical treatment were carried on. Among the more promising were double treatment with lime, high alum dosage, ozone, sodium silicate and break-point chlorination. It was during these experiments that the excellent flocking ability of sodium silicate in hard Florida waters was discovered and, as a result, at least six softening plants in the state, where color is not a great problem,

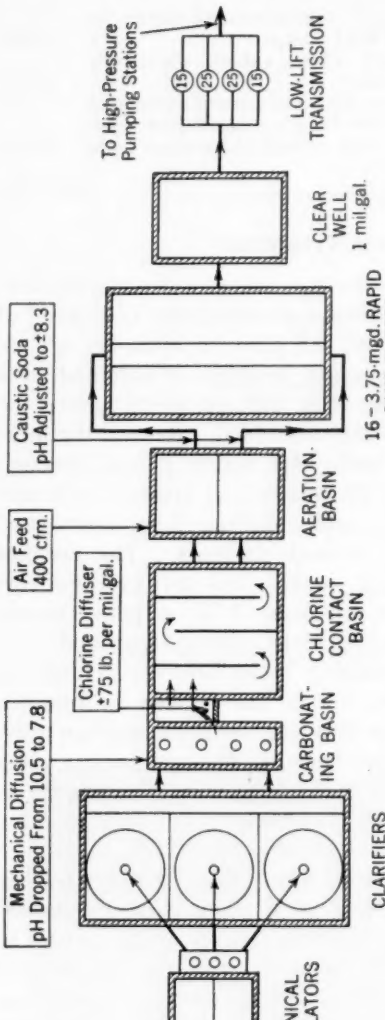

Fig. 4. Flow Diagram of Proposed 60-mgd. Water Softening Plant—Miami, Fla.

now use this coagulant exclusively. It was soon discovered, however, that sodium silicate would not remove color and for that reason it was eliminated as a possibility for the Miami plant.

Evaluation of all the results of the experiments led the consulting chemist, Dr. A. P. Black, to recommend break-point chlorination as the treatment that would best remove the last 10 to 15 ppm. of color. The new plant design, therefore, has been built around this treatment.

Plant improvements, the estimated cost of which is $400,000, in addition to the equipment costs previously listed, will afford the following treatment:

As can be seen in Fig. 4, raw water will pass through two Venturi meters, with new meter registers and a summator from which automatic control of new lime-feed machines and a soda-ash machine will be accomplished. The water will enter two new, specially designed sand traps; then pass through two new flash-mix tanks where lime and alum will be added; then through existing flocculators to the clarifiers, including one new 125-ft. diameter unit of Dorr Si-feed type. The clarifier effluent will pass to a new recarbonating basin in which influent and effluent pH will be constantly checked by means of Bristol pH recording equipment. Effluent pH must be maintained quite constant between the narrow range of 7.5 to 7.8, and this will be accomplished by automatic control of the carbon dioxide gas feed by means of the pH recording and control equipment.

The water will then pass to a chlorinating down-well, where chlorine will be added at an approximate rate of 75-lb. per mil.gal. from the new 3000-lb. chlorine machines, which will be housed in a new building. Numerous experi-

ments, including three six-hour plant-scale runs, have established 75-lb. per mil.gal. as the break-point dose for Miami's water. Automatic control of chlorine feed will be accomplished by converters operated by the raw water Venturi meter differentials. A chlorine contact time of at least one-half hour will be provided by a new basin, in addition to the use of the remodeled present final settling basin. After chlorination the pH will have dropped to slightly under 7.0.

From the contact basin the water will pass to two aerating basins (existing tanks—one now the recarbonating basin) where filtered air agitation will remove excess carbon dioxide and the nitrogen tri-chloride formed in the break-point treatment. As the water leaves the aerating basins, with a pH of from 7.5 to 7.8, caustic soda will be added to stabilize the water by bringing the pH up to about 8.3. Caustic soda will be made by feeding soda ash and lime in a small sludge-blanket type of tank.

The water now will be ready to go on to the filters. New conduits will be built to supplement existing conduits, and the water will be carried to either end of the filter gallery. No new filters will be constructed, as it is planned to increase the filter rate from 2 to 3 gpm. per sq.ft., thereby increasing the present 40-mgd. capacity to 60 mgd.

When the plant is operating at a 60-mgd. rate, the chemicals used daily will be as follows: 53 tons of lime, 2½ tons of alum, 2⅔ tons of soda ash, 2¼ tons of liquid chlorine and 9 tons of carbon dioxide gas.

For some years past the water department has been considering the building of a plant to calcine calcium-carbonate sludge into quicklime. It has now been decided to construct such a plant. A consulting engineer is preparing plans and specifications for an 80-ton-per-day plant which it is hoped will be in operation by the end of 1946. Briefly, this plant will consist of a slurry mix tank where dried sludge from the existing waste pond can be prepared for mixing with the sludge from the clarifiers; two sludge thickener tanks; sludge pumps; a centrifuge for dewatering the sludge to approximately 35 per cent moisture; a rotary kiln, approximately 215 ft. long by 8 ft. outside diameter; oil firing equipment with automatic controls; a lime cooling unit; conveyor and elevator equipment; and a 400-ton storage silo. Pneumatic conveying equipment will be provided for moving lime to the existing chemical house bins, and such equipment will also handle alum and soda ash from a storage warehouse at present under construction at a cost of $40,000.

At the rated capacity of 80 tons of lime per day, there will be discharged from the kiln approximately 115 tons of carbon dioxide gas. About nine tons of this gas will be used in the water plant for recarbonation. Several private interests are ready to bid for the remainder, and it is anticipated that in the next several years as much as 50 tons per day will be processed into liquid carbonic and dry ice. An excess of quicklime also will be produced but no decision as yet has been made concerning its disposal. Preliminary estimates of cost for this plant are $300,000. From 4,000 to 5,000 gal. of fuel oil will be used at the calcining plant each day.

Approximately 55 miles of distribution mains, 12 in. and smaller, have been installed since March 1941. The total average water consumption has increased from 23 to 32.5 mgd.; on the

peak day this past winter 42 mil.gal. left the water softening plant.

In addition to the above projects: a new low-pressure pumping station is contemplated at the water softening plant; elevated tanks are planned for several sections of the metropolitan area; and several existing high-pressure pumping stations are to be modernized.

A distribution study, including a pitometer survey of feeder mains, is now being made in order that the ultimate required capacity of the various high-pressure pumping stations may be better established.

What Water Works Construction Will the Housing Program Require?

The Wyatt report on Emergency Housing promises such a volume of home building as to require foresight and patience from every water works manager. The house building industry is naturally hungry for business. No one denies that houses are needed. So the number one requirement of water works superintendents is that they keep informed concerning FHA authorizations for mass building as well as every individual building permit that is issued in their territory. The FHA is supposed to require prospective builders to check with the management of utilities, such as water, electricity, gas, etc., to the end that utility service is made available to the housing units. But superintendents who wait for information through official channels will be at a disadvantage. Many builders will expect to call today and get water service tomorrow. No one can tell today how many houses will be built or where. No one can tell whether housing units will require long or short supply lines to serve them. But, if the program goes ahead as Wyatt outlined it, it will call for 3,000,000–4,000,000 tons of water pipe, valves, hydrants, meters, pumps and accessories to bring water service to the new houses. This is about three to four times a prewar good building year for water works. It will call for foresight in ordering materials and the utmost diligence on the part of water works manufacturers.

In the meantime every water works superintendent must keep in touch with his city building department, the nearest FHA office, the local Chamber of Commerce, the local newspaper editors, and any other official or person who could be presumed to know anything *in advance* about house building in his city in 1946 or 1947.

The Chemical Engineers' Approach to Industrial Waste Problems

By John E. Tarman

Director, Consulting Div., W. H. & L. D. Betz, Philadelphia, Pa.

Presented on Nov. 16, 1945, at the West Virginia Section Meeting, Wheeling, W.Va.

THE operation of substantially all industries results in waste products. These wastes may be liquid, solid or gaseous. Solid wastes may be discarded on dumps and gaseous wastes may be discharged to the atmosphere. Liquid wastes, as well as certain solid and gaseous wastes, are usually discharged in water-carried form. Except for a minor number of cases, in which the water-carried waste may be discharged into leaching wells for underground disposal, they will eventually find their way into surface waters.

These wastes will have a deleterious effect upon the receiving body of water in various ways and to varying extents, depending upon the nature of the waste discharged, the relative volume with respect to the volume of the receiving body of water and the concentration of the waste.

With increasing industrialization, increased use of surface waters occurs. In the case of a flowing stream, the water may be re-used a number of times by various industries or municipalities between its head waters and mouth. A flowing stream will tend to purify itself, unless its contamination load is excessively heavy, provided it flows for a sufficient distance prior to its re-use. At present, however, many surface streams are re-used with such frequency and contaminated to such an extent by the various users that self-purification is no longer effective.

The present trend toward concentration of industries and expansion of industrial activities, which has taken place over recent years, has resulted in the concentration of waste flows and an increase in the number of points at which the stream is contaminated. Increased activity has also increased the strength and flow rate of the wastes discharged.

The treatment of water-carried wastes for byproduct recovery has become essential in certain industries due to economic competition. It is no longer possible, for example, for a paper mill to operate economically and sell its product in a competitive market unless certain steps are taken to minimize the fiber loss in waste water leaving the mill. The recovered byproducts are of sufficient value to the industry to justify certain expenditures for treating facilities and methods. Byproduct recovery from various industries has been the principal factor behind the major portion of industrial waste treatment undertakings within the past fifteen years.

Industrial waste pollution of streams has progressed to the point where many public water supplies are now menaced. Also affected is the industrial utility of those streams. Industries using the streams as a source of water supply are forced to make extra expenditures to prepare properly the water for their use. Aquatic life in

many streams is menaced, if not now extinct. Many streams now have only a limited recreational value, while others are entirely unfit for recreational purposes.

Legislation and Control

The above factors have resulted in legislation governing the use of water by industry and the characteristics of liquid discharges which can be made to those streams. Variations in local conditions and the intensity of the problem have resulted in non-uniform legislation among the various states. In most cases the legislation is designed to protect public health, but control in some places is arranged to serve other purposes, such as protection of aquatic life or maintenance of the stream in a navigable condition.

Enforcement of the legislation is vested in various hands, depending on the actual legislation and local conditions prevailing. The several states which have enacted pollution control legislation have charged a sanitary water board or the department of health with its enforcement.

Interstate waters have imposed a special problem, since no over-all gain is accomplished if pollution of those waters is controlled by only one of the states. Interstate commissions have been set up in certain instances for the purpose of obtaining uniform control of pollution.

The federal government has been directly interested in the problem of pollution of waterways since 1934, when a committee was appointed to draft plans for legislative action. Two general approaches to the problem were suggested: (1) direct federal control and enforcement of pollution legislation and (2) federal guidance and aid to the state. Three bills are now before the Congress, each embodying a specific approach to the problem and the designation of administrative authority to certain specific agencies. The passage of such legislation will probably result in a greater uniformity and enforcement of pollution standards than now prevails.

The treatment of municipal sewage is a fairly standardized procedure. As a result of pressure exerted by various authorities for cleaning up surface waters, many municipalities have proceeded with the installation of treatment and disposal works, and many others are now preparing plans for such projects to be installed as rapidly as materials for such work become readily available. The treatment of industrial trade wastes, however, presents more specialized technical problems, and progress toward the elimination of this source of pollution has lagged behind. The problem will, therefore, become more acute with industries when the pollution due to the discharge of sanitary sewage has been eliminated or materially reduced.

Many states now require new industries to provide suitable waste disposal facilities at the time of their initial operation. Existing and presently operating industries are continuously being subjected to increased pressure by the appropriate administrative authorities to minimize or stop completely the discharge of wastes.

Waste Treatment Is a Process Problem

The treatment of industrial trade wastes is therefore rapidly becoming a process problem. The present method of classification of streams to establish the amount of pollution which is to be permitted will, if continued, be the prime governing factor.

Trade waste treatment and disposal must be considered at any time a plant location is being selected or a particular manufacturing or processing operation contemplated. The cost of such disposal facilities and methods must be considered as an operating cost of the particular plant or process involved. By the same token, any contemplated future operational changes or expansions must be accompanied by consideration of their effect on existing waste treatment facilities or changes in those facilities which must be effected.

Industry must also give proper and adequate consideration to the effect of possible future legislation and control of industrial waste discharges on the selection of plant processes and plant locations.

The problem of industrial waste disposal should receive the same consideration as any processing problem. It should be subjected to an appropriate amount of research and engineering and economic consideration in determining the most feasible procedure. Treatment of wastes will represent an item of cost in manufacturing operations. Recovery of usable and valuable byproducts will, in many cases, at least partially offset the cost of the treatment, but it cannot be counted upon to offset the entire cost.

Classification of Wastes

Industrial wastes are usually complex in nature and subject to certain inherent variations. The wastes themselves will be as numerous as the products manufactured or processed by the industries. Variations will obviously occur among industries engaged in different types of operation and even in the same type of industry, depending on the actual processes employed. The waste within any one plant may also vary with time, as manufacturing processes may be changed or modified. Every industrial waste problem must, therefore, receive individual study and evaluation before a satisfactory and economic solution can be evolved.

While industrial trade wastes are of widely varying characteristics they may be roughly classified either as organic or chemical. Organic wastes will originate from industries which process food products, laundries, distilleries and breweries, pulp and paper mills, and others. These wastes are highly putrescible, giving rise to obnoxious odors, and are characterized by a high content of fatty, nitrogenous and carbonaceous material. They are ordinarily of vegetable or animal origin. Domestic sewage falls into this classification.

Organic wastes will consume oxygen from the receiving stream during their breakdown into simpler and more stable compounds. This action is accelerated or catalyzed by organisms present in the receiving stream or in the waste itself. If a sufficient quantity of oxygen is present in the stream to supply that required for stabilization of the waste, self-purification of the stream will result and septic conditions will be avoided. In many cases, however, the supply of oxygen in the stream is insufficient for this purpose and septic action takes place. Odorous gases are formed and the depleted oxygen supply cannot support aquatic life, and the water is unsuited as a supply for municipal use.

Chemical wastes will be of widely divergent types and may contain any of the known chemicals or compounds, depending on the raw materials used in the particular industry, the processes involved and the final products manufactured. Industries producing this

type of waste include steel mills, by-product coke plants, metal plating, oil refineries and many others.

The action on the receiving stream will be almost as widely variant as the wastes themselves. For present consideration, however, certain of the chemical wastes may be considered as toxic. In this classification may be listed specific poisons and other substances which, if present in sufficient concentrations, would render the water unfit for human consumption and unsafe for aquatic life.

Certain chemical wastes will impart taste and odor to the receiving stream, thus interfering with its use as a potable water supply. Inert materials, while not particularly harmful in themselves, will settle out on the stream bottom, filling up the stream bed and interfering with the feeding ground of aquatic life. In extreme cases, frequent dredging of the stream may be necessary to maintain it in a navigable condition. Oil, while essentially an inert material, will rise to the surface of the stream, forming an oil slick. This prevents the re-oxygenation of the stream through natural sources and renders the stream unsuitable for recreational uses.

Internal Plant Studies

In any plant faced with a problem of treatment and disposal of its industrial trade wastes, investigations within the plant itself should first be conducted. The investigations should cover the uses of water in an effort to minimize the quantity. In many cases, the quantity of material lost from a certain process will be almost a direct function of the flow of water leaving that process. By minimizing the flow of water, therefore, the wastage of the product may also be minimized. Water cost normally represents a fair portion of the raw material cost, so that the use of minimum quantities of water may effect appreciable savings in total manufacturing costs.

Re-use of water within the plant should also receive detailed consideration as one means of reducing the net water discharge from the plant. Re-use should be considered on both the "as is" basis and also following reconditioning. Re-use of water without treatment can often minimize the total amount of product lost in the water-carried waste.

If the water needs reconditioning prior to re-use, the treatment necessary to effect this reconditioning will be widely variant in different specific problems. In the reconditioning process, recovery of certain valuable by-products may be accomplished, in which case the total waste discharge is minimized. In any case of re-use, either with or without treatment, a lower cost for the plant water supply will result.

After the internal plant studies have been completed and corrective steps have been taken, a minimum quantity of waste will actually be leaving the mill and will be in a minimum quantity of water. The actual waste disposal problem which then requires solution can be determined and defined. In most cases, the results which can be accomplished by the internal plant study will effect savings and economies which will more than offset any processing or treatment costs which may be involved within the plant. Since such changes will result in a reduction of the total waste discharge, economies in the external treatment necessary will be possible.

The internal plant studies will be most effective if made by chemical en-

gineers experienced in waste treatment work in co-operation with engineers familiar with the particular plant and its process problems.

Treatment Requirements

After the volume of actual waste has been reduced to a minimum, it may be possible in certain instances to avoid further treatment. Some manufacturing plants are located within areas served by municipal sewerage systems and may find it possible to discharge their waste through the city sewerage system. This constitutes the simplest method of disposal where it can be practically applied. In other instances, primary treatment of the industrial waste may be necessary prior to its admission into the city sewerage system. On certain classifications of streams, also, primary treatment of the resultant waste may prove sufficient, at least for the time being and until classification of the particular stream is revised. Where treatment, either primary or complete, is required, every attention should be given to the possible recovery of byproducts which may have a sales value or which can be reused within the processes of the plant itself. It should be borne in mind, however, that the primary purpose of waste treatment is to render that waste satisfactory for discharge either into city sewers or into a surface water supply. Obtaining byproducts is desirable in order to minimize the cost of the treatment process but is of no particular interest to the authorities charged with the enforcement of pollution legislation.

The characteristics and quantities of the waste leaving the plant, after all possible internal plant changes have been made or designed to effect their reduction to a minimum, must be determined. This is accomplished by taking necessary flow measurements and conducting the required analytical work. The chemical engineer then gives consideration to the applicability of the various tools or unit processes customarily applied to waste treatment problems. Many of the tools and unit processes are similar to those customarily employed in water treatment practice, while others are specific and have been devised for application to these problems.

It should be borne in mind that, while the industrial wastes may be grossly objectionable within any stream, the actual quantities of materials present in those wastes are relatively low, seldom exceeding in total a fraction of 1 per cent. It can therefore be readily realized that treatment to accomplish removal or reduction of these relatively small quantities of impurities presents an engineering problem of a specialized nature.

Mechanical Treatment Methods

As in water treatment practice, most processes will involve, at some stage, the separation of liquid and solid components. Any one or several of the mechanical separating arrangements may be applied, depending upon the particular conditions involved. Screening of the wastes will effect a separation of the larger solid particles from the liquid portion and may be used for particle sizes of rather small magnitude by the use of a sufficiently fine screen. Mechanical difficulties with the use of extremely fine screens render this method not practical for separation of very fine solids in most cases.

Solid particles in finer states of subdivision can be separated by sedimentation. This method depends on a gravity differential between the com-

ponents to be separated. Either settling or skimming, or both, may be applied to a sedimentation tank in order to obtain the desired separation.

Filtration of the waste may be applied either for clarification of the waste or for dewatering the solid fraction. A centrifuge, either of the continuous or batch type, may be applied for similar purposes, treating either the previously separated sludge or the entire volume of wastes, as the particular case may require.

Flotation is a specialized form of sedimentation in which the solid material entraps air, causing it to rise to the surface for removal. Flotation may be carried out either under atmospheric pressure or under vacuum. Chemical aids are sometimes employed to assist in this operation.

The application of vacuum to a sedimentation tank has been made to accomplish both settling and flotation within the same unit. This is a relatively new development and will probably find more widespread use in the future. In such a unit, two solid layers are separated and removed, eliminating the necessity of forcing a readily settleable material to float or to settle a difficultly settleable fraction.

Evaporation can be applied economically to certain wastes. This evaporation may be of the solar type, taking place in a lagoon, or may be in mechanical evaporators. Normally, evaporation cannot be economically applied unless byproduct recovery can be realized from the process. Installations of this type have been made for the treatment and disposal of distillery slop, products being obtained which are useful as stock feed.

Constituents found in certain industrial trade wastes can be removed by adsorption, for example on activated carbon. The carbon can be subsequently treated for stripping off this adsorbed material, thereby accomplishing recovery of the material.

Sludge Disposal

Any waste treatment system will ultimately present the problem of disposal of sludge. Various methods have been employed to accomplish this. Where adequate ground area is available, solar drying of the sludge can be accomplished in lagoons or sludge drying beds. Rotary or spray dryers can be applied where space limitations prevent the use of solar drying. Obviously, operating costs will be higher with either the rotary or spray dryer.

In certain instances, disposal of even the dried sludge may present a residual problem. In such cases, the sludge may be incinerated. Certain sludges may possess some fuel value, although usually not enough to support their own combustion. It is therefore usually necessary to provide an external source of heat on such incinerating operations. On sludges containing a valuable ash content, the incineration process may, at least in part, be of economic advantage. It also permits recovery and re-use of certain constituents, such as lime, when present in sufficient quantities.

Final decision on sludge drying methods and the use of incineration can be based only upon detailed economic considerations of the several factors prevailing in any specific problem.

Chemical Treatments

Chemical flocculation and precipitation find application in the treatment of certain industrial wastes, either alone or followed by other treatment. These processes are carried out in a

manner similar to the treatment of water and in similar types of equipment. Recently, application of the rapid upflow type of clarifier has been made on an experimental basis to the treatment of industrial trade wastes. It has been in use for several years on water clarification and softening problems and accomplishes flocculation, precipitation and separation of the solid and liquid components in one unit and with a minimum of tankage. Operating experience to date indicates that it can be successfully applied to waste treatment problems and may, in certain instances, be effective without the use of chemical coagulating aids.

Flocculation and precipitation are used primarily as aids in sedimentation. They therefore serve the same purpose as in normal water treatment practice. The coagulating aids used must be selected for the particular waste undergoing treatment and will usually be alum, ferric sulfate, ferric chloride or sodium aluminate. Chemical flocculation is also employed on occasion to assist in breaking emulsions and as an aid in flotation.

Certain chemical wastes will be highly acid or highly alkaline and will require neutralization prior to discharge. A sufficient degree of neutralization may sometimes be accomplished by compounding the wastes discharged from the plant, taking advantage of the interaction of acid and alkali wastes. Final neutralization by feeding an acid or alkali may, however, be required even after compounding to accomplish final neutralization.

Industrial wastes which contain highly oxidizing or reducing components require neutralization of those factors prior to discharge. Of the two, oxidizing treatments are the more common. These are special treatments and are employed only on special cases where it is necessary to produce a stable treated effluent.

Biological Treatment Methods

The biological treatment methods customarily employed in the treatment of sanitary sewage also find application on trade wastes. In general, biological processes depend on the action of organisms on the waste undergoing treatment. These methods may be applied in various ways; in some cases the organisms are moved through the waste undergoing treatment, and in other cases the organisms remain stationary and the waste flows. Oxygen may or may not be required in the biological treatment, depending on the results desired and the type of organism causing the action to proceed.

Biological treatments may be generally divided into two classifications. One requires the presence of oxygen and is known as aerobic action. The first common application of this treatment is in the trickling filter where the organisms build up on the layer of rock and the waste undergoing treatment percolates down through this layer. The second common method of application of aerobic treatment is the activated sludge process. In this process, the organisms are circulated through the waste, effecting oxidation and stabilization. Of the two, the trickling filter is more generally used in industrial trade waste treatment owing to the fact that it is less susceptible to shock resulting from change in flow rate or characteristics of the waste. This is an important factor in trade waste treatment because the characteristics may fluctuate widely and rapidly.

The second classification of biological treatment takes place in the absence of air and is designated as anaerobic.

It finds limited use in waste treatment, being normally confined to the treatment of sludge resulting from some other process. The sludge is stored in a tank without access to air where it undergoes digestion with the production of gas. Thermophilic digestion is applied on occasion to speed up the rate of digestion and obtain digestion of certain constituents in the sludge which respond to this type of treatment with greater difficulty. This process requires the use of somewhat elevated temperatures during the digestion period.

Accessory Mechanical Devices

In the application of any of the foregoing processes, certain basic engineering problems require solution. Materials handling problems will require solution and may involve handling liquids, slurries or solids. Many of the materials to be handled will be of corrosive nature and proper attention must be given to materials of construction of the handling equipment.

Mixing and agitation are required in several of the processes and may be accomplished either by baffle mixing, air agitation or mechanical agitation. Of the three, mechanical agitation is generally more efficient, but cost considerations may lead to a final selection of one of the other types.

Problems of measurement and control are frequently encountered. The normal factors requiring this consideration are flow, pH and temperature.

Where chemical methods are employed, feeding arrangements will be required for those chemicals. The quantities to be handled will determine whether dry feeding or liquid feeding equipment is preferable. Either type may operate on a constant or proportional rate basis. For proportional feeding, the problem must be correlated and considered together with such items as flow or pH measurement and control.

Functions of the Chemical Engineer

From the foregoing, it will be apparent that the successful treatment of an industrial trade waste will depend on the application of the appropriate unit process or processes to the special problem as presented. The engineer who is called upon to solve the problem must therefore apply his background of experience in the field for the proper evaluation of the various factors involved and the selection of the proper type of treatment.

The engineer must also inform himself and his client of applicable regulations set up by the proper administrative bodies. The engineer's interpretations of the regulations prevailing must also be made and applied to the particular problem under investigation. The engineer must also represent his client at the required conferences with the administrative authorities, preparing necessary permit application forms as needed.

Where industrial wastes can be discharged into municipal sewerage systems, the most economical solution of the problem will be obtained. It should be pointed out, however, that preliminary treatment may be required for the waste prior to discharge into such sewers. It is also necessary that the municipal treatment plant be of adequate capacity and of proper type to handle the added load imposed by the industrial waste without sacrificing efficiency of stabilization. Court decisions have been to the effect that industries may be required to withdraw from municipal sewerage systems if operating experience indicates that the municipal

treatment plant can not satisfactorily handle the municipal and industrial load. The industries may be required to withdraw at any time during their discharge into the sewers. A permit from the municipality operating the sewerage system and treatment plant is normally required before the industrial waste may be discharged into the system.

In making a final design, the engineer must take into account all local conditions then prevailing or anticipated, processes and operations of the plant, probable expansions or modification of the processes and the permissible characteristics of wastes which may be discharged.

While the treatment of industrial trade wastes will, in most cases, represent an added cost of operation, the proper utilization of experienced engineers will minimize this cost to the plant faced with such a problem.

Veterans Emergency Housing Program

Nelson Wyatt, Housing Expediter, on Feb. 8, 1946, made a report to President Truman which may have far reaching effects upon the country's construction activities for several years. Wyatt recommends that instead of the present program of 400,000 homes in 1946 a new program be authorized. He wants to start construction of 2,700,000 homes before the end of 1947 of which 1,600,000 will be conventional homes, 850,000 prefabricated homes and 250,000 temporary units. The previous all-time high was 937,000 homes in 1925.

The program awaits congressional authorization but we may safely assume that a housing program very much along the lines of Wyatt's report will get under way by mid-year.

(See page 332 for comments concerning the meaning of this program to water works.)

Water and Electricity *Do* Mix

By Earl E. Norman

Mgr., City Light and Water Utilities, Kalamazoo, Mich.

A contribution to the Journal

IT has been said that water and electricity do not mix, but in Kalamazoo, Mich., these services are closely integrated; the city operates both an electric utility and a water utility, under the managership of the author.

Electricity and water, after all, do have much in common. For example, they both require conductors; water is distributed through hollow pipes and electricity through copper or aluminum conductors. Moreover, electrical conductors are not always solid; in cases of very high frequencies, high currents or high voltages they are sometimes hollow.

Pressure loss through a water pipeline increases approximately as the square of the load or flow. Power loss through an electric transmission line also increases as the square of the load. Kalamazoo's water utility uses centrifugally-cast iron pipe, while the electric utility uses centrifugally-cast concrete ornamental street light posts!

In a well-managed plant the electrical energy, as well as the water recorded on customers' meters, should be between 80 and 90 per cent of the amount produced at the generating plant or pumping station.

It may be seen from the tabulation below that in Kalamazoo the amount of water accounted for and the amount of electrical energy accounted for are essentially the same.

	%
Water Utility	
Recorded on customers' meters	87.39
Drinking fountains (estd.)	0.33
Fires, hydrant flushing, etc. (estd.)	0.48
SUBTOTAL	88.20
Standard leakage—A.W.W.A.*	3.49
Actual water unaccounted for	8.31
TOTAL PUMPAGE	100.00
Electric Utility	
Recorded on customers' meters	75.60
Street lighting and traffic signals	13.90†
SUBTOTAL	89.50
Auxiliary plant use	5.13
Distribution losses and unaccounted for	5.37
TOTAL OUTPUT AT GENERATOR TERMINALS	100.00

* Refers to A.W.W.A. Specifications for Laying Cast-Iron Pipe, Sec. 15.2—Permissible Leakage.

† Not an estimate; 80% registered on meters installed for this specific purpose.

An investigation of the percentage of water and electricity accounted for in six representative municipalities in Michigan gave the following results:

	Accounted-for Production %	
Utility	*Water*	*Electric*
A	88	88
B	86	86
C	84	92*
D	81	88
E	88	90
F	87	90

* This figure includes electricity used in the plant; the others do not.

FIG. 1. Specially Designed Truck Used by Trouble Crew at Kalamazoo, Mich.

Consolidation and integration have been applied to every activity possible. About one-half of the permanent year-around employees work at one time or another for both utilities. The only men who never work for both utilities are the men in the power plant—the boiler operators, the turbine operators and their assistants.

The electric utility has its line crews, which are mainly occupied with the care of the electric utility's distribution system. The same line crews, however, maintain and take care of the overhead wires for the control of pumping facilities, which are owned by the water utility. The water utility has men familiar with underground construction (water pipes) and these same men install underground electric conduits.

One of the best examples of consolidation at Kalamazoo is the so-called "trouble crew." This trouble crew has at its disposal a specially designed truck (Fig. 1), with all the facilities necessary for emergency work for both the water and the electric utilities. The truck is equipped with an overhead ladder for taking care of traffic signals and overhead wires. It carries keys for operating underground water distribution valves and is equipped with a detailed map of both the electric and water distribution systems; it carries spare electric and water meters,

and is continuously manned 24 hours a day, on call by means of a two-way police radio. The men who operate this truck are primarily electrical men, but before they are allowed to operate the truck or to work on the trouble crew they are given a special course of training in the water utility, so that they may become familiar with the testing and servicing of water meters, the location of water troubles, leaks, etc.

One of the trouble men is normally used whenever it is necessary to splice an underground lead-covered electric cable, but one of the water service connection men, who is nominally a plumber, is also qualified to splice lead-covered electric cable—and sometimes does.

In the business and commercial fields of the utilities there is even more similarity. Occasionally, a customer of both utilities, for one reason or another, will use more gallons of water or more kilowatt hours of electricity than usual and will complain of high bills. Customers of both utilities must be handled with the same degree of diplomacy and the same care must be exercised relative to credit and collections. (Kalamazoo does not hold water bills as a lien against property; it can do so but chooses not to, as a matter of good public relations.)

The general office, the commercial office, payroll accounting and billing are all handled by the same personnel and in the same office. Both electric and water meters are read by the same meter readers. Separate and complete financial statements and balance sheets are prepared for each utility, but the accounting for both is handled by the same personnel. Every man in the organization, from the manager to the minor temporary employee, turns in a daily report showing the distribution of his time to the different accounts of the two utilities.

Relative to the basic administration of the utilities, there is a Manager of City Light and Water Utilities, who is appointed by, and holds office at the pleasure of, the City Manager. He has four assistants reporting directly to him: the Water Works Superintendent, who is responsible for the maintenance and operation of the entire water works system outside of the administrative and commercial office; the Lighting Plant Superintendent, who in the same manner is responsible for the operation and maintenance of the entire electrical system; the Utilities Accounts Supervisor, who has general charge of the commercial office, meter readers, public relations, etc.; and the Construction Superintendent, who supervises construction in both utilities. It is believed that this arrangement has worked out for the greatest maximum over-all economy.

New Method for Cutting Cast-Iron Pipe

By Wendell R. LaDue

Supt. & Chief Engr., Bureau of Water & Sewerage, Akron, Ohio

A contribution to the Journal

FOR some time leakage had been observed adjacent to the gatehouse of the equalizing reservoir at Akron, Ohio. This reservoir is of the covered type and has a capacity of 20 mil.gal., about one-half day's supply during peak consumption.

The leakage was believed to be through expansion joints in the reservoir wall, since the leakage appeared to be greater in the winter when the joints were wider, and also because more leakage was observed with a full reservoir than when the water was at a lower elevation.

From time to time the water in the reservoir was lowered, and the expansion joints were calked with lead wool. The leakage continued, however, and during the summer of 1944 it was decided to expose the outside of the joint opposite the point of observed maximum leakage. The joint was exposed for its entire depth and no leak was found.

Continued observation in the vicinity disclosed that the grass over an adjacent connecting main remained green throughout the hot summer drought. The connecting main was isolated by closing the valves to the reservoir and to the force mains. The flow of water which had been observed stopped almost immediately and began again as soon as water was supplied to the connection. After this discovery it was certain that the leak was in the connection.

The connection of 36-in. cast-iron pipe, 52 ft. in length, is the only connection between the equalizing reservoir and the force mains and distribution system. The average cover over the connection is approximately 14 ft. With a full reservoir the head on the pipe is 32 ft. (14 psi.).

Construction information was meager. It was known that the pipe was 36-in. Class A pipe furnished under a contract dated Sept. 12, 1912. The average weight of the pipe was 4,804 lb. per 12-ft. length, or slightly over the standard weight of 4,700 lb. per length. A piece of pipe removed calipered 0.99 in. thick, which is standard for Class A cast pipe. The connection was laid under a contract dated Feb. 6, 1913.

It was necessary to excavate a trench 19 ft. in depth by approximately 9½ ft. wide for a distance of approximately 25 ft. to expose the pipe. The excavation was complicated by the necessity of furnishing adequate support for the footing of a 15-ft. retaining wall abutting the excavation and for a concrete wall which crossed the trench at right angles.

The trench was excavated and sheeted as shown on Fig. 1. Excavation was facilitated by a crane with a clamshell bucket and the excavated material hauled away. The sheeting

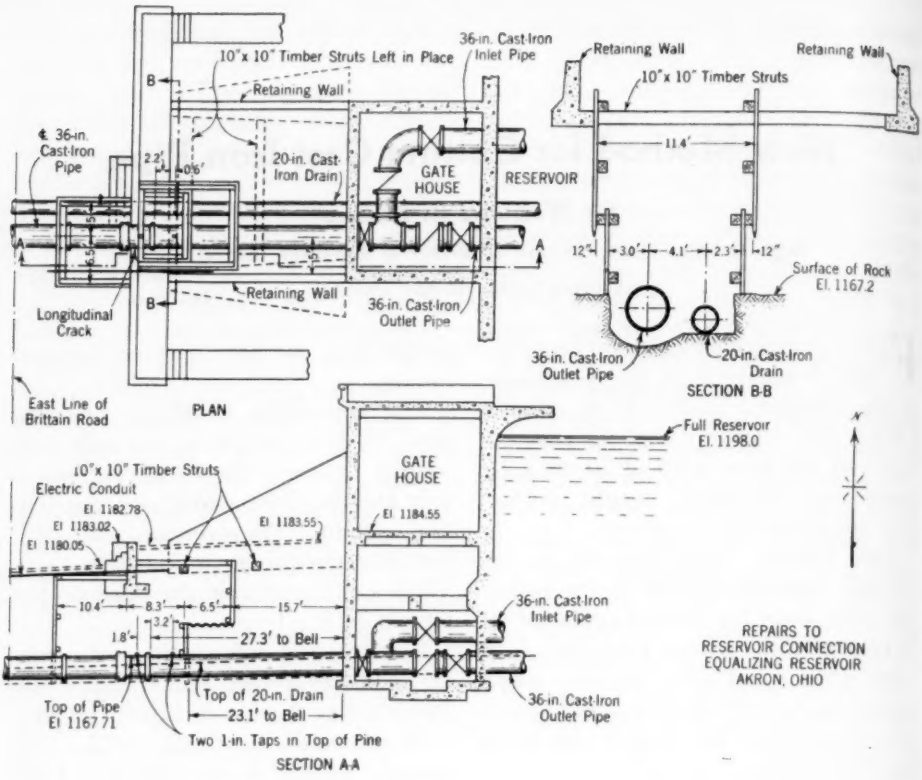

FIGURE 1

was hand-driven, and 24-hour pumping was carried on to insure dry working conditions. The head on the pipe was reduced by carrying lower reservoir elevations, but the reservoir, of necessity, remained in service.

Upon exposing the pipe, it was found that the lead in a joint had "blown" and most of the leakage was coming from the top of the pipe. The lead was driven home sufficiently to hold the water; the trench dried up and pumping discontinued.

While engaged in calking the joint a 3-ft. longitudinal crack was discovered in the bottom of the pipe extending through the bell. Due to the low head on the pipe, together with the relief offered by the "blown" joint, no leakage had appeared through the crack. This condition changed a relatively easy repair job into a major one. The broken bell was almost directly under the cross wall, preventing easy removal and replacement of the pipe. The pipe was in rock, which also added to the difficulty of excavation.

Thought was given to two methods of making a repair as follows:

1. Welding in place. This was not deemed advisable, since the crack was in the bottom of the pipe and would require the melting of the joint and the rotation of the pipe.

2. Removal of a portion of the pipe and its replacement with a bell-and-

spigot piece of pipe and a sleeve. This method was adopted.

In order to make the repair, it was necessary to resort to direct pumping. A study of the Saturday and Sunday consumptions for the months of September and October indicated that the pumping station could carry the load without low-lift pumping from about 11:00 P.M. Saturday to 6:00 A.M. Monday. Accordingly, preparations were made to make the repair on the night of October 21 and 22. The pumping station was notified and followed the load curve during the shut-down.

As noted above, the 36-in. pipe was Class A, about 1 in. thick. Considerable thought had been given to the method of cutting the pipe. A relatively new process of cutting cast-iron pipe with an electric torch was tested at the water works storage yard.

A 36-in. bell-and-spigot piece, with laying length 5 in. shorter than the piece to be cut out of the 36-in. connection, was cut at the yard. This served as a dress rehearsal for the cutters.

The cutting involved a circumferential cut of 10 lin.ft. and a longitudinal cut, including the bell, of 4 ft. The first step was to burn a hole through the pipe at the end of the crack to prevent possible additional cracking due to temperature changes during the cutting. The circumferential cut was then made with two cutters working on opposite sides of the pipe, one cutter working to the top, the other to the bottom. The direction was then reversed, completing the cut. The longitudinal cut was made on top of the pipe, diametrically opposite the crack. The cutting of the bell was done in longitudinal passes, cutting into the bell for its entire length rather than attempting to cut through the bell at one time. The dross dropping into the pipe was porous and easily removed. The cut averaged $\frac{1}{2}$ in. in width and the edges were clean and very true to line. Considerable thought was given to the marking of the line so that it could easily be seen through the colored shields worn by the cutters. The line was marked with a chisel and the chisel markings were connected with white chalk.

Two truck-mounted generators with automatic voltage regulators were used to supply the current for the cutting torches. In cutting the pipe 300 amp. were used. This was increased to 350 amp. when cutting the bell. About 31 lb. of "Fleetweld," $\frac{3}{16}$-in. No. 5 coated rod were used for the 14 lin.ft. of cutting.

When the cutting was completed, wedges were driven into the longitudinal cut, splitting the pipe cleanly along the crack at the bottom. The old pipe was removed and the repair was completed with a bell-and-spigot piece and a solid sleeve. The joints were made of lead substitute and braided hemp.

The shut-off was started at 8:00 P.M., and the line was down and drained by 10:00 P.M. Several valves, which were not seriously affecting distribution system pressure, were closed in advance of the actual shut-down. Cutting was started at 11:30 P.M. and completed at 2:00 A.M. The pipe repair was completed by 6:00 A.M. and by 6:30 A.M. the reservoir was back in service.

Automatic Operation of a Small Filtration Plant

By E. H. Greenwald and H. E. Davis

Eng. Dept., Boone County Coal Corp., Sharples, W.Va.

Elec. Dept., Boone County Coal Corp., Sharples, W.Va.

Presented on Nov. 16, 1945, at the West Virginia Section Meeting, Wheeling, W.Va.

THE Boone County Coal Corporation, with general offices at Sharples, Logan County, W.Va., has recently erected at Sharples, on Spruce Fork of Little Coal River between Madison and Logan, a small filtration plant that is unusual in its degree of automatic control of operation. The company has extensive coal reserves and operates a large mine at Monclo on Beech Creek about 1 mile south of Sharples, and the problem of supplying a sufficient quantity of safe and potable water to its employees is an important one, complicated because employees live in communities some distance apart. Aside from Monclo and Sharples, camps are also maintained at Dobra, about 1 mile north of Sharples on Spruce Fork, and Clothier, about 3 miles north of Sharples.

Prior to March 1945, and since their establishment, all camps were dependent on water from drilled wells, each community being equipped with its own well, pump, storage tank and distribution system. Experience over many years indicated that drilled wells were not reliable from the standpoint of quantity and, after sporadic trouble with the supply at Monclo through the late thirties and early forties, a thorough study of the problem was made.

Basically the problem was that of an adequate supply, for all available sources could be of good quality after various degrees of treatment. Of the possible sources, including drilled wells, mine drainage and surface water, it was decided that Spruce Fork, with a mountainous drainage area of some 50 square miles upstream from Sharples, would be most permanent as a primary source of supply. In addition, the location of the plant at Sharples allowed the inclusion of a good drilled well then in use there as a secondary supply. Furthermore, mine drainage between Sharples and Dobra was another possible alternate, if for any reason the surface and/or well water proved inadequate.

There was little upstream contamination, other than that from humans in the sparsely populated areas. An analysis disclosed the surface water to be of excellent quality, with results from one test as follows:

Alkalinity	23 ppm.
Total Iron	0.1 ppm.
Chlorides	2 ppm.
Hardness	46 ppm.
pH	6.3

The quality of the well water compared favorably with the quality of the surface water, as can be seen by the following:

Alkalinity	130 ppm.
Total Iron	0.4 ppm.
Chlorides	8 ppm.
Hardness	80 ppm.
pH	7.0

On the basis of this information the type of treatment required was determined. The surface water required features of a standard rapid sand filtration plant, namely, facilities for coagulation, settling, filtration, chlorination and corrosion control. These same facilities would be usable in reducing the quantity of iron in the well water, as well as the hardness, if desired. Consumption data gathered over previous years and the prediction of future needs served as the basis for determining the size of plant. A figure of 100 gpm. was set as the desired capacity. In addition to the communities of Sharples and Monclo, this figure also included Dobra as it was deemed advisable to furnish this camp with treated water from the Sharples plant. At present this rate requires the plant to operate only 7 hours out of 24, producing an average of 42,000 gal.

Filter Operation

After having decided on the source, the type of treatment and the capacity desired, the primary consideration then became the operation cost. Realizing that this type of plant would be costly to operate, not from the standpoint of chemical consumption, but in attendance cost, careful attention was given to the primary design and selection of equipment which would assure full flexibility of automatic control.

Figure 1 is a flow diagram of the plant. Coagulation and settling take place in a 32,000-gal. 5-hour retention, redwood tank, with the necessary mixing and flow control baffles. The addition of lime and alum as the coagulants is by two Syntron "Vibra-Flow," model CFM-1-30, dry feeder machines operating on single-phase 110-v. current, equipped with full and intermittent control rheostats and electrically connected to the raw water intake pump by means of a 220 v.–110 v. relay. These feeders are located on an operating floor that extends partially over the settling tank. Water to the solution pots of the feeders is supplied through a ½-in. line from the clear well pump to the storage line, which has the full storage pressure on it at all times. The flow of water is controlled by a normally closed solenoid valve electrically connected to the feeders, thus allowing a flow of water only when the feeders are in operation.

Filtering takes place in two units of 25 sq.ft. each. Filters are composed of 18 in. of graduated gravel and 30 in. of sand, with brass underdrains conducting filtered water to the clear well. The filter tanks and 2,400-gal. clear well were cast monolithicly of reinforced concrete. In finishing the clear well, a white tile bottom was installed and the walls were painted with three coats of Inertol Company "Ramuc" white enamel. A concrete cover, which acts as the clear well pump base, was cast over half the well, and the other half was fitted with a plate-glass viewing panel. A light was installed as an aid in viewing the finished water.

The clear well pump is a Pomona 13-stage, 6-in. turbine operating at 1,750 rpm., with a Westinghouse 5-hp., 220-v., 3-phase, 60-cycle motor. The latter is a duplicate of motors already in use with Pomona pumps on the Sharples and Clothier drilled wells, as it was considered desirable to standardize from the point of maintenance. As mentioned above, the pump motor base is directly over the clear well, with the column line and turbine bowls extending to within 6 in. of the bottom of the well, which is 16½ ft. deep. The pump delivers approximately 100 gpm. to storage tanks of 36,000-gal. capacity

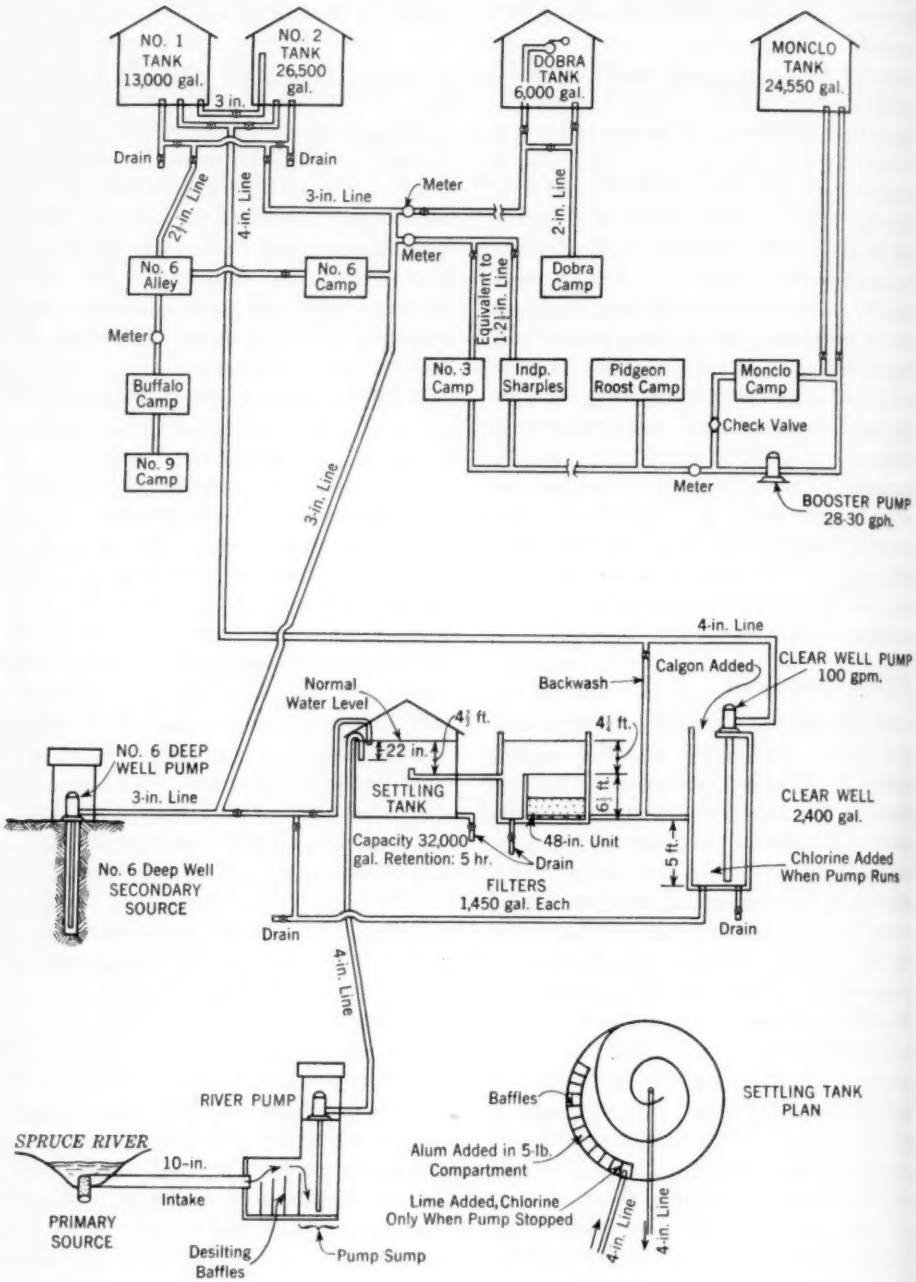

FIG. 1. Diagram Showing Flow of Domestic Water—Sharples, W.Va.

some 160 ft. higher in elevation on a hill behind the plant.

A Wallace and Tiernan chlorinator of the continuous gas feed type is in use at the plant, along with a diversion valve developed by employees of the company. The valve is of hard rubber construction to resist the action of the chlorine and is actuated by a Mercoid damper control motor connected electrically with the clear well pump by means of a relay. Chlorine feed is over 24 hours, being fed into the settling tank when the clear well pump is idle and into the clear well when the pump is running, thus guaranteeing a chlorine residual in the water going to storage.

Due to the corrosiveness of surface water, Calgon is added as a corrosion control reagent in the clear well at the rate of 1 lb. per 24 hours by gravity solution feed from a 54-gal. barrel.

Facilities for backwashing consist of a branch take-off from the 4-in. pump to the storage tank line connected into the underdrain manifold header and fitted with orifice flanges and an orifice plate that allows the passage of 375 gpm. as the proper backwash rate. Water direct from the storage tank is thus used in carrying out backwashing.

Facilities for pumping raw surface water into the settling tank are located on the stream bank about 600 ft. from the plant and at a point above the last sewage inlet from Sharples. Because the normal flow of water in Spruce Fork varies from less than 6 in. to several feet, the design of the intake was a difficult one. The design itself is based on a C & O Division of Water Supply plan of a pump station located at Clothier. Water is taken into a 10-ft. length of 10-in. steel pipe with 1,800 $\frac{3}{16}$-in. perforations. This pipe is laid on the stream bed extending downstream. Water entering this intake is conducted by additional 10-in. pipe to a desilting and sump tank of reinforced concrete located on the stream bank. Upon entering this tank the velocity is decreased, causing suspended solids, mostly sand, to be trapped and deposited behind four desilting baffles. A Pomona 4-stage, 6-in. turbine, with a 1,750 rpm., 5-hp. motor, a duplicate of the clear well pump motor, handles the water to the plant from the sump. Although this pump requires only $1\frac{1}{2}$ hp. in delivering 110 gpm. to the settling tank through 600 ft. of 4-in. line, it was desirable from the point of standardization to install this pump with a 5-hp. motor. The use of a turbine permitted the erection of the pump house directly over and some 14 ft. above the bottom of the sump, which is approximately 3 ft. lower than the level of the stream bed, thus placing the pump at an elevation high enough to be out of the reach of flood waters.

Water from the drilled well as a secondary source is brought either to the settling tank or directly to the clear well by 300 ft. of 3-in. line. Although a Pomona deep well pump had been delivering water from the well to the storage tanks at the rate of 57 gpm. under a 5-hp. load, it was found that the same pump would deliver approximately 95 gal. to the settling tank under a $3\frac{1}{2}$-hp. load, thus requiring no changes in the rate of plant operation when the well is used as the source of supply. To date the well has been used several times during periods of high water to avoid treating surface water heavy with sediment. In order to keep both well and pump in operating condition, however, the pump operates approximately 1 hour in every 24. It is controlled automatically by the use of two G.E. magnetic switch controls and a G.E. time switch control which transfers the power from the stream pump

to the deep well pump between 9:30 and 10:45 A.M., with the use of only one Westinghouse De-ion line starter for both pumps.

The normal operating cycle, regardless of the source of supply, is controlled by two level control switches. A G.E. float-type switch is installed in one of the storage tanks which operates through a 6-in. differential below the overflow point of the tanks, and is wired into the clear well pump starter circuit. A Bender-Warick electrode-type switch is installed in the settling tank, operating through 4 in. just below the overflow point of the tank and wired into the river and deep well pump starter circuit. With the settling tank, filter tanks and clear well having a common top elevation, the flow of water is gravitational.

The normal cycle can be assumed as beginning with all equipment idle, the diversion valve flowing chlorine to the settling tank, the water level the same elevation from settling tank to clear well at a point just touching the top electrode of the settling tank control switch, and the water level in the storage tanks above the bottom setting of the storage tank float. When consumption lowers the water level in the storage tanks to the bottom setting of the storage tank float switch, the float throws the power on the clear well pump which lowers the level of water in the clear well at the rate of 100 gpm. and at the same time powers the diversion valve motor which changes the flow of chlorine to the clear well and then shuts off. In turn, due to the difference in head thus created, water passes through the filters to the clear well and from the settling tank to the filters, lowering the level of water in the tank. When the level drops below the bottom electrode of the control switch in the settling tank, the surface or deep well intake pump is powered, furnishing raw water to the settling tank. At the same time and through means of a relay the feeders and solenoid valve previously mentioned are powered and the feeding of coagulants at the proper rate begins.

The operation as outlined continues until the clear well pump has furnished sufficient water to the storage tanks to raise the level to the top setting off the float switch, thus cutting the power from the pump and returning the chlorine flow to the settling tank. Approximately 1,800 gal., plus what goes to distribution during the pumping interval, is required to do this, representing a pumping time of at least 18 minutes. Flow from the settling tank to the filters to the clear well, however, continues until the same level is reached in all three, which may not occur if the clear well pump again starts to operate. In any event the level of water in the plant never goes above the top electrode setting in the settling tank, which controls the breaking of the circuit to the intake pump and interconnected equipment. When the surface intake is in use the intake pump may shut down several times while the clear well pump completes a run. This is due to its greater capacity. The deep well pump when in use more nearly approaches the output of the clear well pump, thus operating over practically the same time interval.

In order to control the maximum loss of head and to prevent the clear well pump from breaking suction, a level control switch of the electrode type is installed in the clear well and wired ahead of the storage tank float in the pump starter circuit. The bottom electrode is set 8 ft. below top water level and the top electrode about 5 ft. below. Thus, when the loss of head at 100 gpm. becomes greater than

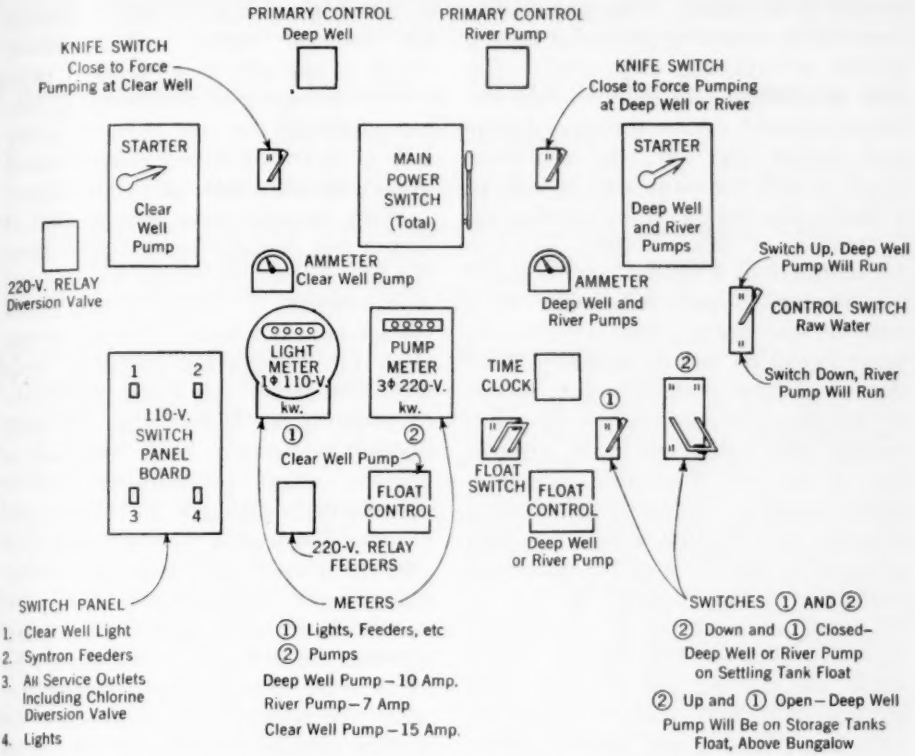

FIG. 2. Electrical Control Panel in Filter Plant—Sharples, W.Va.

a maximum 8 ft., the clear well pump will be shut off after drawing the water level to below the bottom electrode. The top electrode will again return the pump to service after the water reaches the 5-ft. level. When this condition is approached backwashing is required.

Another secondary level control switch of the electrode type is installed in the surface water sump to protect the surface intake pump from breaking suction, if at any time it pumps water at a rate greater than can gravitate into the sump. This has occurred only once in six months and was due to sand accumulation in the 10-in. intake pipe, a situation easily remedied.

All control boxes for the above-mentioned controls have been mounted on a panel board located in the filter plant (see Fig. 2). In addition, the board also contains kilowatt-hour and ampere meters for the various circuits. Included too are single-knife switches that permit the forced operation of any circuit for testing purposes. Because it is desirable to retain the possible use of the deep well pump, which pumps directly to storage, a double-throw switch, controlling the circuit on which the deep well pump will operate, is also found on the board.

Operation Problems Encountered

As could be expected with the amount and variety of electrical controls in use, a few operating problems developed. The first to be encountered was the inaction of the electrode-type level controls due to the low mineral

content of the water. This was readily corrected by installing grounded copper shields around the electrodes. The next trouble to develop involved the human element. After testing the clear well circuit one day, the attendant failed to pull the knife switch and, as a result, the storage tanks overflowed. Correction of this difficulty included the addition of a buzzer on the panel board which sounds when the clear well or raw water intake circuits are being forced, as well as rewiring of the clear well level control switch to cut off the clear well pump when the water reaches the bottom electrode, regardless of whether the knife switch is closed or open. The latest troublesome problem, and one that lacks a desirable solution as yet, concerns the continued operation of the chemical feeders on the intake circuit after the safety level control switch at the surface water sump has cut out the surface water pump. Although this has occurred only once, it was not discovered for several hours and as a result the settling tank had a thorough overdosing of lime and alum.

Cost of Operation

The actual attendance cost of operating the Sharples plant is about $1.00 per day, which, at the rate water is now being furnished, amounts to approximately 2½ cents per 1,000 gal. The total operating cost, including chemical, power and attendance costs, averages less than 8 cents per 1,000 gal. Experience has shown that several trips to the plant every 24 hours by the attendant are sufficient to check the operation of the equipment, especially the chlorinator, and 15 minutes in the evening to make the usual laboratory checks on treatment and quality of water, as well as to add Calgon to the solution barrel. Backwashing, which is normally needed about twice a week, requires an additional ½ hour each day. At the time of backwashing ½ lb. of activated carbon is batch-dosed to each filter for taste and odor control.

With storage tanks also located at Dobra and Monclo, system attendance has been eliminated except for an occasional check. Installed in the Dobra storage tank is a float control valve that shuts off the gravitational flow from the Sharples tanks at a point below the overflow of the Dobra tank. A small booster pump has been installed at Monclo, where gravitational flow is only partially effective, for it will supply the distribution but will not flow into the storage tanks desirable for the maintenance of continuous line pressure and fire protection. This pump operates on a float control switch located in the Monclo tank, running only when the water level drops below the bottom setting of the switch. In order to realize full benefits of gravitational flow, a bypass around the pump allows distribution-to-use directly from the Sharples supply, drawing only from the storage tanks when consumption exceeds the delivery of the Sharples to Monclo lines.

Summary

Six months of actual operation has shown that a small filtration plant automatically controlled from the point of intake to storage is practical and can accomplish its purpose, that is, to reduce the operational attendance cost to a minimum. The increase in plant-installation cost in order to gain automaticity has easily been compensated for by this reduced cost.

Fluorescence of Drinking Waters As Evidence of Sewage Pollution

By Ruth A. McLean and Mamie L. Speas

Sr. Bacteriologist, West Virginia State Hygienic Lab., Charleston, W.Va.

Jr. Chemist, North Carolina State Lab. of Hygiene, Raleigh, N.C.

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RENAL secretions are known to contain substances in considerable concentrations which show fluorescence in ultra-violet light (1, 2, 3) and raw sewage shows fluorescence (4). With these facts in mind, measurements of the fluorescence of certain specimens of drinking water were made. Tests were made on the same specimens for the presence of *Escherichia coli* and bacteria belonging to the coliform group.

The work reported is preliminary in scope and was done in spite of the fact that a variety of substances which might be present in drinking waters from sources other than human excrement are known to produce fluorescence. Certain radioactive metals (5), numerous inorganic salts (6), mineral oil (7), tar, resin, pitch (8) and products of the metabolism of certain microorganisms and compounds released in decaying organic matter (9, 10) are a few of the possibly many substances in this category.

The purpose of the investigation was to determine whether or not polluted specimens of water would fall into a given range as to fluorescence and thus be separated, without bacteriological tests, from non-polluted specimens. Such a study was made possible by the availability of instruments designed to measure accurately the intensity of fluorescence.

Experiments

Specimens of water for bacteriological examination were collected from wells, lakes and springs in North Carolina, according to specifications of the North Carolina State Laboratory of Hygiene. All specimens were examined bacteriologically for the presence of members of the coliform group and all specimens showing fermentation in lactose bile broth were then plated on eosin-methylene blue agar in order to confirm the presence or absence of *Esch. coli*. Seventy-five specimens were tested for the presence of coliform organisms and for intensity of fluorescence.

Measurements of fluorescence were made on a Coleman Photofluorometer, Model 12, with the B 1-S filter. Distilled water was used as a standard solution. Specimens were collected over a period of one week and stored in the cold room immediately after completion of the bacteriological examination. All measurements of fluorescence reported in Tables 1 and 2 were made on the same photofluorometer within two successive days. It was thought that by this means the variables of light intensity inherent in mercury vapor lamps would, for practical purposes, be removed. Those specimens which showed turbidity

TABLE 1

Fluorescence of Well and Spring Waters as Related to Presence of Escherichia coli

Specimen Number	Description Source of Water		*Esch. coli**		Fluorescence			
	Source	Depth of Well, *ft.*	10 ml.	1 ml.	Tested Water	Distilled Water	Final Value	
					T	D	T–D × Dilution	Result
					Galvanometer Divisions			
1	Dug pump well		+	+	33	15	33–15×0	18
2	Open dug well	30	+	+	29	15	29–15×0	14
3	Hand pitcher pump well		+	+	58	15	58–15×5	215
4	Protected spring		+	+	35	15	35–15×0	20
5	Dug pump well	36	+	+	22	15	22–15×0	7
6	Protected spring		+	−	24	15	24–15×0	9
7	Protected spring		+	−	24	15	24–15×0	9
8	Protected spring		+	+	45	15	45–15×0	30
9	Bored pump well		+	+	35	15	35–15×0	20
10	Pitcher pump well	300	+	−	20	15	20–15×0	5
11	Dug pump well	45	+	−	22	15	22–15×0	7
12	Drilled pump well	600	+	−	22	15	22–15×0	7
13	Dug pump well	85	+	−	28	15	28–15×0	13
14	Drilled pump well	30	+	−	24	15	24–15×0	9
15	Bored pump well	40	+	−	71	15	71–15×0	56
16	Dug pump well		+	−	63	15	63–15×0	48
17	Dug well	25	+	−	32	15	32–15×0	17
18	Dug pump well	40	+	−	65	15	65–15×0	50
19	Spring		+	−	26	15	26–15×0	11
20	Well		+	+	31	15	31–15×0	16
21	Dug pump well		+	+	74	15	74–15×0	59
22	Drilled pump well		+	+	69	15	69–15×0	54
23	Bored pump well	40	+	+	20	15	20–15×0	5
24	Hand pitcher pump well	206	+	+	85	15	85–15×5	350
25	Open spring		+	+	30	25	30–25×0	5
26	Drilled pump well	240	−	−	40	15	40–15×5	125
27	Drilled pump well	260	−	−	38	15	38–15×5	115
28	Drilled pump well	85	−	−	28	15	28–15×0	13
29	Drilled pump well		−	−	29	15	29–15×0	14
30	Bored pump well		−	−	28	15	28–15×0	13
31	Protected mechanical system		−	−	22	15	22–15×0	7
32	Pitcher pump well		−	−	42	15	42–15×0	27
33	Bored pump well		−	−	22	15	22–15×0	7
34	Bored pump well		−	−	30	15	30–15×0	15
35	Bored pump well	35	−	−	23	15	23–15×0	8
36	Bored pump well	225	−	−	25	15	25–15×0	10
37	Drilled pump well	90	−	−	22	15	22–15×0	7
38	Drilled pump well	260	−	−	38	15	38–15×5	115
39	Protected spring		−	−	35	15	35–15×0	20
40	Bored pump well		−	−	40	15	40–15×0	25
41	Drilled pump well	106	−	−	19	15	19–15×0	4
42	Bored pump well		−	−	30	15	30–15×0	15
43			−	−	26	15	26–15×0	11
44	Bored pump well	300	−	−	23	15	23–15×0	8
45	Pitcher pump well	30	−	−	31	15	31–15×0	16
46	Pitcher pump well	20	−	−	22	15	22–15×0	7
47	Dug pump well	30	−	−	18	15	18–15×0	3
48	Protected mechanical system		−	−	22	15	22–15×0	7
49	Drilled pump well	72	−	−	18	15	18–15×0	3
50	Drilled pump well	90	−	−	17	15	17–15×0	2
51	Drilled pump well	500	−	−	19	15	19–15×0	4

* *Esch. coli* present or absent in 10 ml. or 1 ml. of water tested—*Standard Methods.*

TABLE 2

Fluorescence of Well and Spring Waters as Related to Presence of Coliform Bacteria in Absence of Escherichia coli

Specimen Number	Description Source of Water: Source	Depth of Well, *ft.*	Lactose Fermentation: Bacteria of Coliform Group 10 ml.*	*Esch. coli* 10 ml.†	Fluorescence: Tested Water T	Distilled Water D	Final Value: T–D × Dilution	Result
					Galvanometer Divisions			
1	Dug pump well	40	+	–	20	15	20–15×0	5
2	Dug bucket well	15	+	–	26	15	26–15×0	11
3	Bored pump well	50	+	–	24	15	24–15×0	9
4	Running stream–cow pasture		+	–	20	15	20–15×50	250
5	Drilled pump well	80	+	–	21	15	21–15×0	6
6	Dug pump well	30	+	–	35	15	35–15×0	20
7	Dug pump well	25	+	–	21	15	21–15×0	6
8	Bored pump well	20	+	–	43	15	43–15×0	28
9	Pitcher pump well	20	+	–	32	15	32–15×0	27
10	Dug pump well	34	+	–	22	15	22–15×0	7
11	Bored pump well		–	–	28	15	28–15×0	13
12	Protected spring		–	–	25	15	25–15×0	10
13	Drilled pump well	46	–	–	22	15	22–15×0	7
14	Bored pump well	35	–	–	20	15	20–15×0	5
15	Drilled pump well		–	–	30	15	30–15×0	15
16	Drilled pump well	175	–	–	29	15	29–15×0	14
17	Drilled pump well	100	–	–	24	15	24–15×0	9
18	Dug pump well	60	–	–	24	15	24–15×0	9
19	Dug pump well	50	–	–	35	15	35–15×0	20
20	Bored pump well	30	–	–	62	15	62–15×0	47
21	Drilled pump well	85	–	–	22	15	22–15×0	7
22	Dug pump well	40	–	–	29	15	29–15×0	14
23	Dug pump well	70	–	–	25	15	25–15×0	10
24	Dug pump well	45	–	–	23	15	23–15×0	8

* Coliform organisms present or absent in 10 ml. of water tested—*Standard Methods.*
† *Esch. coli* present or absent in 10 ml. of water tested—*Standard Methods.*

were made crystal clear by centrifugation before being tested for fluorescence. The test consisted of making one reading on a tube of water after having first set the photofluorometer with the standard solution. With the B 1-S filter, distilled water read between 15 and 20 galvanometer divisions, varying slightly from time to time. The photofluorometer was therefore set at 15, with distilled water as a standard, before reading each unknown. For that reason, 15 was subtracted from each reading to obtain the final value. This procedure was arbitrarily followed in an effort to secure comparable figures for intensity of fluorescence produced by any substances which were present in the various waters and which would fluoresce in the 365-mμ mercury band passed by the B 1-S filter. No attempt was made to determine the specificity of fluorescing substances in the waters.

The figures recorded in Tables 1 and 2 are comparable, because, as previously stated, they were obtained with the same photofluorometer, which, according to checks with the standard solution, retained a given sensitivity throughout the series of readings. Some readings obtained have not been included in this report because fluctuations were noted in the meter available.

The same conclusions regarding increased intensity of fluorescence of a certain percentage of all specimens of water showing the presence of *Esch. coli* could most likely be obtained by another worker. The same or similar figures, however, might not be obtained. Distilled water from at least two different sources has been found to give totally different readings in three photofluorometers of the same make and model. This discrepancy is, at least in part, due to the fact "that the instrument sensitivity is dependent on the intensity of the mercury vapor lamp, which in turn depends on the voltage and frequency of the power supply. These factors vary with time" (11) and also with the age of the lamp, i.e., the number of hours it has been used. A photofluorometer recently fitted with a new mercury lamp and new batteries gave a much higher reading for distilled water than another with older lamp and batteries. It is not considered impossible, however, to standardize conditions so that conductivity water would always give the same reading as to intensity of fluorescence. Conductivity water was not used in any of the experiments herein reported.

In an effort to compare the sensitiveness of a test for intensity of fluorescence of water and the bacteriological test for *Esch. coli,* dilutions of feces and urine were measured for fluorescence by the same technic as is used in making measurements on waters. Both urine and feces gave measurable amounts of fluorescence in dilutions of 1–1000 but not in dilutions of 1–100,000,000. Intermediate dilutions were not tried. Suckling (12) states: "The number of viable bacteria of the species *Bacterium coli* in human faeces amounts to several hundred millions per gramme; if the low figure of a hundred millions be accepted, it follows that the addition of faeces to water, to the extent of only 1 part per hundred millions, would result in the immediate presence of *Bacterium coli* in so small a quantity as 1 cc."

A cork in the metal lid of a standard water container from the North Carolina State Laboratory of Hygiene, which was slightly charred by repeated sterilization, was macerated in distilled water. The suspension was centrifuged and the amber-colored, clear, supernatant fluid was tested for fluorescence. It gave a final value of 19 after 15 was subtracted from the reading of 34. This was done because the specimen in a bottle with such a cork gave a higher reading than was anticipated. It is suggested that specimens of water to be tested for fluorescence should be collected in glass-stoppered bottles.

Results and Discussion

Results of bacteriological tests and of tests for intensity of fluorescence are recorded in Table 1 for 24 specimens from which *Esch. coli* was isolated and for 26 specimens from which no organisms of the coliform group were isolated. Similar results are recorded in Table 2 for specimens bacteriologically positive or negative for the coliform group, from none of which *Esch. coli* could be isolated. Intensity of fluorescence is indicated by the use of numbers listed under "Fluorescence" in Tables 1 and 2. The numbers are arbitrary units of measurement—actually galvanometer deflections as recorded in scale divisions—and are referable, as previously noted, only to the work reported in this paper. Outstanding is the fact that readings greater than 100 occurred in all of the three groups into which the examined

waters fell: (a) specimens positive for *Esch. coli,* (b) specimens positive for the coliform group but negative for *Esch. coli* and (c) specimens negative for members of the coliform group. Three of the readings greater than 100 occurred in the 26 negative specimens listed in Table 1 and three in the 34 specimens positive for coliform organisms in Tables 1 and 2. Since, however, four out of six of them were from wells 200 ft. or more deep, the intensity of fluorescence was most likely due, in large part, to the high mineral content of such waters (6). It is a well-known fact that waters from deep wells are often high in mineral content in contrast to surface waters, including those of shallow wells and of springs.

Omitting those specimens reading 100 or more, the five specimens in Table 1 giving a reading of 50 or more were all found positive for *Esch. coli.* These amounted to 8 per cent of the 51 specimens. It is suggested that if statistical studies (made with a standardized rapid technic for measuring intensity of fluorescence of waters) should confirm, in principle, the findings of this preliminary study, it might be possible to omit bacteriological work on a significant number of all routine specimens from wells and springs. Intensity of fluorescence could quickly be determined for all specimens for analysis, and those falling within a range known always to give bacteriological findings for coliform organisms could be reported presumptively without bacteriological examination. Probably the same application could not be made to treated waters because chemical treatment might add fluorescing substances of non-fecal origin to the water, and fluorescing substances of fecal origin might remain in solution in the water through treatment even though coliform organisms were killed or removed.

The preliminary experiments reported in measuring the intensity of fluorescence of dilutions of fecal material indicate that fluorescence could be useful in detecting only heavily polluted specimens, if increased intensity of fluorescence of polluted waters be due entirely to materials derived from feces or urine. It is possible that bacteria of the coliform group synthesize fluorescing substances and that ever-increasing amounts of them from that source, in addition to those extracted from urine and feces, would thus occur in a polluted water. So far as the authors are informed, *Esch. coli* has not been reported to synthesize such materials, though, as previously noted in this paper, other bacteria have been so reported (9, 10).

An investigation roughly similar to the one reported here was made by Ivekovic in Yugoslavia in 1931 (8). His measurements of fluorescence were made against gelatin standards. Fluorescence was indicated by numerals 1–4, with 1 indicating minimum, 4 maximum and 2 and 3 intermediate degrees of fluorescence. He reports that the intensity of fluorescence is proportional to the oxygen absorption as measured by the potassium permanganate demand. He concluded that a test of the degree of fluorescence was useful in eliminating the necessity for further examination (referring to bacteriological tests) except for those specimens showing the weakest fluorescence (8). The latter, within the limits stated, is in accord with our results. He stated that a test of the degree of fluorescence has been made a part of the routine examination of waters in the Laboratory of the Zagreb Institute for Hygiene in Yugoslavia. Such a test,

he states, is particularly helpful in detecting, immediately, evidence of sewage pollution in large plants where the water is tested hourly or several times daily. According to him, a particular water supply may be known to give, regularly, a certain degree of fluorescence. A marked increase in fluorescence is viewed with alarm. This application would seem to indicate that the principal value of a fluorescence test for sewage pollution would be its rapidity and ease of manipulation. These advantages would be gained, as stated earlier in this paper, with a loss in sensitivity, of undetermined degree, as compared with present bacteriological methods.

The authors believe that testing of large supplies as described by Ivekovic (8) for quick detections of variations from a known usual reading, would probably constitute the greatest value of a routine test for fluorescence of drinking waters. Further work, however, is anticipated in an effort to make a statistical study of fluorescence of waters in relation to the occurrence of *Esch. coli,* with the idea of applying a measurement of fluorescence, as suggested previously, to the routine testing of untreated waters.

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Drinking Water Standards—1946

THE U.S. Public Health Service, under its authority over interstate quarantine matters, has issued four successive standards of quality for water used on interstate carriers. These documents were released in 1914, 1925, 1942 and 1946. The 1946 standards are published hereinafter. Each document, when it appeared, was intended by the U.S.P.H.S. for use in evaluating the quality of water furnished or made available to passengers on railroad trains, steamships or other forms of transport known as common carriers and traveling across state lines. As time progressed, the nature and extent of the standards impinged in increasing degree upon practices, equipment and structures used in production of public water supplies. It has therefore become difficult to consider the details of these standards simply as they relate to water as it might be used on a common carrier. It has become, on the contrary, increasingly evident that clarity of thinking in matters related to water supply sanitation would be greatly promoted by development of the standards in terms which might be applicable to all water supplies, followed by their voluntary acceptance by an organization of water works executives, such as the A.W.W.A.

When the 1942 standards were promulgated, portions thereof were of such nature as to require their review in conferences between officers of the U.S.P.H.S. and representatives of the A.W.W.A. These conferences and the adjustments derived therefrom led the A.W.W.A. Board of Directors, early in 1945, to the conclusion that ultimately standards might be developed which were both adequate for the interstate control activities of the U.S.P.H.S. and applicable to intrastate waters, if voluntarily accepted by the water works industry.

It will be understood that the authority of the U.S.P.H.S. to promulgate and act upon the terms of drinking water standards resides in its jurisdiction over interstate health matters. This authority is not claimed by the Service to extend to water used in intrastate activities.

It will also be understood that the A.W.W.A. has no authority to promulgate or enforce a standard of quality for public water supplies. It can, however, for its membership, voluntarily accept such standards for application to water supplies under the control of its members, and thus by implication make them professional standards commanding the broad and general acceptance to which such documents are entitled.

The Board of Directors of the A.W.W.A., therefore, after careful consideration and deliberation, on Jan. 14, 1946, adopted the following resolution:

WHEREAS, The Officers and Directors of the American Water Works Association are desirous of supporting all efforts to promote better health through safe water supplies, and

WHEREAS, It is noted that the Standards of the U.S.P.H.S. are promulgated by the Surgeon General for use in the administration of Interstate Quarantine Regulations, and that they

are intended to apply only to water used on common carriers engaged in interstate commerce, and

WHEREAS, It does not appear that the Surgeon General desires or proposes to extend the authority of the U.S.P.H.S. to include any water supplies other than those used by common carriers subject to Federal Quarantine Regulations, and

WHEREAS, It is the desire of the A.W.W.A. to have available for reference, to recognize and to accept fair and effective standards for quality of water furnished by all public water supply systems, and

WHEREAS, The Officers and Directors of the A.W.W.A. have studied the text of the proposed 1946 Drinking Water Standards which have been developed by the Surgeon General of the U.S.P.H.S. and found the terms and conditions of these Standards to be constructive, and

WHEREAS, It is the earnest hope of the A.W.W.A. that, as a result of its voluntary acceptance of the Drinking Water Standards as criteria of quality of all public water supplies in the United States, the state boards of health and their sanitary engineering personnel will find it possible to further constructive and co-operative relationships with the water works management to the ends that deficiencies in water suply systems be corrected as promptly as feasible; that extraneous sources of contamination of water be eliminated; and that encouragement be given to training and employment of qualified personnel in positions of responsibility in the operation of water works,

NOW THEREFORE BE IT RESOLVED by the Officers and Directors, acting for the American Water Works Association, that the 1946 Drinking Water Standards proposed for adoption by the U.S.P.H.S. be voluntarily accepted by our Association as the standards for all public water supplies.

U.S.P.H.S. Drinking Water Standards—1946

The standards included herein have been promulgated as Regulations of the United States Public Health Service and published in the Federal Register. These standards supersede the standards adopted Sept. 25, 1942, and recommended by the Advisory Committee on the Revision of the 1925 Drinking Water Standards. They are recommended and approved by the same Advisory Committee.

Effective upon their date of publication in the Federal Register, these regulations represent standards to which drinking water and water supply systems used by carriers and others subject to Federal Quarantine Regulations must conform. These standards are in a form believed suitable for use generally in evaluating quality and safety of water and water supply systems.

(S) THOMAS PARRAN
Surgeon General
United States Public Health Service

Approved: February 6, 1946

(S) MAURICE COLLINS
Acting Administrator
Federal Security Agency

Report of the Advisory Committee on Official Water Standards[1]

Experience gained by the Certifying Authority during three years' utilization of the Standards adopted in 1942 indicates a need for revision of wording and clarification of certain sections of these Standards. During the period these Standards were in effect it became necessary to issue State Health Officers' Circular Letter No. 85 in order that the Standards would be properly and uniformly applied. It is believed desirable to have the Standards worded in such a manner that they are suitable for utilization without further clarification.

Heretofore drinking water standards adopted by the Public Health Service have been designed to apply specifically to those water supplies used by carriers subject to the Interstate Quarantine Regulations. The present revision contemplates a standard for water quality generally acceptable and applicable to all public water supplies in the United States.

It has been with these two objectives in mind that this revision of the Standards has been effected. No major changes have been made in the basic requirements of the Standards, but certain requirements have been restated in such a manner as to make them more readily applicable to existing water supplies. In writing these Standards in a manner that will allow their application to all public water supplies, no inference is meant or desired that the authority of the Public Health Service should be extended to include any water supplies other than those used by carriers subject to the Federal Quarantine Regulations.

It will be noted that the *Manual of Recommended Water Sanitation Practice* referred to in the preface to the 1942 edition of the Standards has not been included in this edition. While this manual was intended merely as an advisory guide, in practice it was found that, at times, it was being used as a part of the Standards and for this reason is omitted from the present text.

Part I—Public Health Service Standards

Hereinafter italics are used to indicate new or revised text, except in the cases of paragraph headings and titles of books, which were italicized in the 1942 edition and continue to be.

1. Definition of Terms

For the purpose of these Standards the terms designated herein below shall be defined as follows:

1.1. *Adequate protection by natural agencies* implies various relative degrees of protection against the effects of pollution in surface waters; dilution, storage, sedimentation, the effects of sunlight and aeration and the associated physical and biological processes which tend to produce natural purification; and, in the case of ground waters, storage in and percolation through the water-bearing material.

[1] The reader is referred to the Report of the Advisory Committee on Official Water Standards in the 1942 edition of the Public Health Service Drinking Water Standards (Jour. A.W.W.A., **35**: 96 (1943)), partly from the standpoint of historical interest, but primarily because the basic ideas expressed in the statement are still valid.

1.2. *Artificial treatment* includes the various processes commonly used in water treatment, both separately and in combination, such as storage, aeration, sedimentation, coagulation, rapid or slow sand filtration, chlorination and other accepted forms of disinfection. Rapid sand filtration treatment is commonly understood to include those auxiliary measures, notably coagulation and sedimentation, which are essential to its proper operation.

1.3. *Adequate protection by artificial treatment* implies that the method and degree of elaboration of treatment are appropriate to the source of supply; that the works are of adequate capacity to support maximum demands, are well located, designed and constructed, are carefully and skillfully operated and supervised by properly trained and qualified personnel, and are adequately protected against floods and other sources of pollution. The evidence that the protection thus afforded is adequate must be furnished by frequent bacteriological examinations and other appropriate analyses showing that the purified water is of good and reasonably uniform quality, a recognized principle being that irregularity in quality is an indication of potential danger. A minimum specification of good quality would be conformance to the bacteriological and chemical requirements of these Standards, as indicated in Sections 3 and 4.

1.4. *Sanitary defect* means any faulty structural condition, whether of location, design or construction of collection, treatment or distribution works which may regularly or occasionally *prevent satisfactory purification of the water supply or* cause it to be contaminated from extraneous sources. *Among the extraneous sources of contamination of water supply are dual supplies, bypasses, cross-connections, interconnections and back-flow connections.*

1.5. *Health hazard* means any faulty operating condition, including any device or water treatment practice, which, when introduced into the water supply system, creates or may create a danger to the well-being of the consumer.

1.6. *Water supply system* includes the works and auxiliaries for collection, treatment and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.

1.7. *The coliform group of bacteria* is defined, for the purpose of these Standards, as including all organisms considered in the coli-aerogenes group as set forth in the *Standard Methods for the Examination of Water and sewage*, current edition, prepared, approved and published jointly by the American Public Health Association and the American Water Works Association, New York City. The procedures [1] for the demonstration of bacteria of this group shall be those specified herein, for:

(*a*) The completed test, or

(*b*) The confirmed test when the liquid confirmatory medium brilliant green bile lactose broth, 2 per cent, is used, providing the formation of gas in any amount in this medium during 48 hours of incubation at 37°C. is considered to constitute a positive confirmed test, or

(*c*) The confirmed test when one of the following liquid confirmatory media is used: crystal violet lactose broth, fuchsin lactose broth or formate ricino-

[1] This reference shall apply to all details of technique in the bacteriological examination, including the selection and preparation of apparatus and media, the collection and handling of samples, and the intervals and conditions of storage allowable between collection and examination of the water sample.

leate broth. For the purpose of this test, all are equivalent, but it is recommended that the laboratory worker base his selection of any one of these confirmatory media upon correlation of the confirmed results thus obtained with a series of completed tests, and that he select for use the liquid confirmatory medium yielding results most nearly agreeing with the results of the completed test. The incubation period for the selected liquid confirmatory medium shall be 48 hours at 37°C. and the formation of gas in any amount during this time shall be considered to constitute a positive confirmed test.

1.8. *The standard portion of water* for the application of the bacteriological test may be either:

(*a*) Ten milliliters (10 ml.) or

(*b*) One hundred milliliters (100 ml.).

1.9. *The standard sample* for the bacteriological test shall consist of five (5) standard portions of either:

(*a*) Ten milliliters (10 ml.) or

(*b*) One hundred milliliters (100 ml.) each.

In any disinfected supply the sample must be freed of any disinfecting agent within twenty (20) minutes of the time of its collection.[2]

1.10. *The certifying authority* is the Surgeon General of the United States Public Health Service or his duly authorized and designated representatives. *Reference to the certifying authority shall be applicable only in the cases of those water supplies to be certified for use on carriers subject to the Federal Quarantine Regulations.*

The reporting agency shall be understood to mean the respective *official state health agencies* or their designated representatives.

[2] In freeing samples of chlorine or chloramines, the procedure given in the *Standard Methods for the Examination of Water and Sewage*, current edition, shall be followed.

2. As to Source and Protection

2.1. The water supply shall be:

(*a*) Obtained from a source free from pollution; or

(*b*) Obtained from a source adequately purified by natural agencies; or

(*c*) Adequately protected by artificial treatment.

2.2. The water supply system in all its parts should be free from sanitary defects and health hazards, *and all known sanitary defects and health hazards shall be systematically removed at a rate satisfactory to the reporting agency and to the certifying authority. Approval of public water supplies by the reporting agency and the certifying authority will be conditioned by the existence of:*

(a) *Rules and regulations prohibiting connections or arrangements by which liquids or chemicals of unsafe, unknown or questionable quality may be discharged or drawn into the public water supply;*

(b) *Provisions to enforce such rules and regulations effectively on all new installations; and*

(c) *A continuing program to detect health hazards and sanitary defects within the water distribution system.*

2.21. *Applications—For the purposes of these Standards, responsibility for conditions in the water supply systems shall be considered to be held by:*

(a) *The water purveyor from the source of supply to the connection to the customer's service piping, and*

(b) *The owner of the property served and the municipal, county or other authority having legal jurisdiction from the point of connection to*

the customer's service piping to the free-flowing outlet of the ultimate consumer.

3. As to Bacteriological Quality

3.1. *Sampling*—The bacteriological examination of water considered under this section shall be of samples collected at representative points throughout the distribution system.

The frequency of sampling and the location of sampling points on the distribution system should be such as to determine properly the bacteriological quality of the water supply. The frequency of sampling and the *distribution* of sampling points shall be *regulated jointly by the reporting agency and the certifying authority after investigation by either agency, or both,* of the source, method of treatment and protection of the water concerned.

The minimum number of samples to be collected from the distribution system and examined by the reporting agency or its designated representatives each month should be in accordance with the number as determined from the graph presented in Fig. 1 of these Standards [3] which is based upon the relationship of population served and minimum number of samples per month:

Population served	*Min. no. of samples per mo.*
2,500 and under	1
10,000	7
25,000	25
100,000	100
1,000,000	300
2,000,000	390
5,000,000	500

In determining the number of samples examined monthly, the following samples may be included, provided all results are assembled and available for inspection and the laboratory methods and technical competence of the personnel are approved by the reporting and certifying agencies:

(a) *Samples examined by the reporting agency.*

(b) *Samples examined by local health department laboratories.*

(c) *Samples examined by the water works authority.*

(d) *Samples examined by commercial laboratories.*

Daily samples collected following an unsatisfactory sample as provided in Sections 3.22 and 3.24 shall be considered as special samples and shall not be included in the determination of the number of samples examined monthly. Neither shall subsequent unsatisfactory samples in this daily series be used as a basis for prohibiting the supply, provided that (1) immediate and active efforts are made to locate the cause of such contamination, (2) immediate action is taken to eliminate such cause, and (3) samples taken following such remedial action are satisfactory.

The laboratories in which these examinations are made and the methods used in making them shall be subject to inspection at any time by the designated representatives of the certifying

[3] For the purpose of uniformity and simplicity in application, the number of samples to be examined each month for any given population served shall be determined from the graph in accordance with the following:

For populations of 25,000 and under to the nearest 1

For populations of 25,001 to 100,000 to the nearest 5

For populations of 100,001 to 2,000,000 to the nearest 10

For populations of over 2,000,000 to the nearest 25.

authority *and reporting agency*. Compliance with the specified procedures and the results obtained shall be used as a basis for certification, in accordance with the application given below.

3.2. *Application*—Applications 3.21 and 3.22 given below shall govern when ten-milliliter (10-ml.) portions are used and applications 3.23 and 3.24 shall govern when one hundred-milliliter (100-ml.) portions are used.[4]

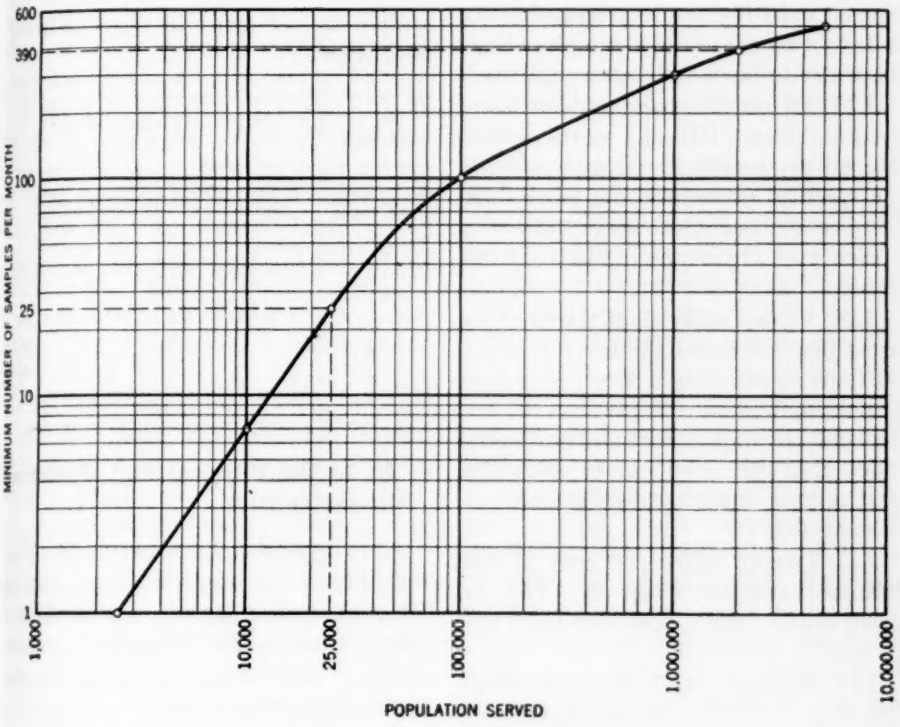

FIGURE 1

3.21. Of all the standard ten-milliliter (10-ml.) portions examined per month in accordance with the specified procedure, not more than ten (10) per cent shall show the presence of organisms of the coliform group.

3.22. Occasionally three (3) or more of the five (5) equal ten-milliliter (10-ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:

(*a*) Five (5) per cent of the standard samples when twenty (20) or more samples have been examined per month.

[4] It is to be understood that in the examination of any water supply the series of samples for any one month must conform to both of the above requirements, either 3.21 and 3.22 or 3.23 and 3.24, respectively.

(*b*) One (1) standard sample when less than twenty (20) samples have been examined per month.

Provided further that when three or more of the five equal ten-milliliter (10-ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.[5]

3.23. Of all the standard one hundred-milliliter (100-ml.) portions examined per month in accordance with the specified procedure, not more than sixty (60) per cent shall show the presence of organisms of the coliform group.

3.24. Occasionally all of the five (5) equal one hundred-milliliter (100-ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:

(*a*) Twenty (20) per cent of the standard samples when five (5) or more samples have been examined per month.

(*b*) One (1) standard sample when less than five (5) samples have been examined per month.

Provided further that when all five of the standard one hundred-milliliter (100-ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.[6]

3.25. The procedure given, using a standard sample composed of five standard portions, provides for an estimation of the most probable number of coliform bacteria present in the sample as set forth in the following tabulation:

No. of portions		M.P.N. of coliform bacteria per 100 ml.	
Negative	Positive	When 5–10-ml. portions are examined	When 5–100-ml. portions are examined
5	0	Less than 2.2	Less than 0.22
4	1	2.2	.22
3	2	5.1	.51
2	3	9.2	.92
1	4	16.0	1.60
0	5	More than 16.0	More than 1.60

4. As to the Physical and Chemical Characteristics

4.1. *Physical characteristics*[7]—The turbidity of the water shall not exceed 10 ppm. (silica scale), nor shall the color exceed 20 (standard cobalt scale). The water shall have no objectionable taste or odor.

[5] When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 10 ml. to 0.1 ml. or less.

[6] When this occurs, and when waters of unknown quality are being examined, simultaneous tests should be made on multiple portions of a geometric series ranging from 100 ml. to 1.0 ml. or less.

[7] *The requirements in Section 4.1 relating to turbidity and color shall be met by all filtered water supplies. Turbidity and color limits for unfiltered waters and the requirements of freedom from taste or odor for either filtered or unfiltered waters should be based on reasonable judgment and discretion, giving due consideration to all the local factors involved.*

4.2. *Chemical characteristics*—The water shall not contain an excessive amount of soluble mineral substance, nor excessive amounts of any chemicals employed in treatment. Under ordinary circumstances, the analytical evidence that the water satisfies the physical and chemical standards given in Sections 4.1 and 4.21 and simple evidence that it is acceptable for taste and odor will be sufficient for certification with respect to physical and chemical characteristics.

4.21. The presence of lead (Pb) in excess of 0.1 ppm., of fluoride in excess of 1.5 ppm., of arsenic in excess of 0.05 ppm., of selenium in excess of 0.05 ppm., of hexavalent chromium in excess of 0.05 ppm., shall constitute grounds for rejection of the supply.

These limits are given in parts per million by weight and a reference to the method of analysis recommended for each determination is given in Section 4.31. Salts of barium, hexavalent chromium, heavy metal glucosides or other substances with deleterious physiological effects shall not be added to the system for water treatment purposes.

Ordinarily analysis for these substances need be made only semi-annually. If, however, there is some presumption of unfitness because of these elements periodic determination for the element in question should be made more frequently.

Where experience, examination and available evidence indicate that such substances are not present or likely to be present in the water supplies involved, semi-annual examinations are not necessary, provided such omission is acceptable to the reporting agency and the certifying authority.

4.22. The following chemical substances which may be present in natural or treated waters should preferably not occur in excess of the following concentrations where other more suitable supplies are available in the judgment of the certifying authority. Recommended methods of analysis are given in Section 4.3.

Copper (Cu) should not exceed 3.0 ppm.

Iron (Fe) and manganese (Mn) together should not exceed 0.3 ppm.

Magnesium (Mg) should not exceed 125 ppm.

Zinc (Zn) should not exceed 15 ppm.

Chloride (Cl) should not exceed 250 ppm.

Sulfate (SO_4) should not exceed 250 ppm.

Phenolic compounds should not exceed 0.001 ppm. in terms of phenol.

Total solids should not exceed 500 ppm. for a water of good chemical quality. However, if such water is not available, a total solids content of 1,000 ppm. may be permitted.

For chemically treated waters, i.e., lime-softened, zeolite or other ion-exchange treated waters, or any other chemical treatments, the following three requirements should be met:

(1) The phenolphthalein alkalinity (calculated as $CaCO_3$) should not be greater than 15 ppm. plus 0.4 times the total alkalinity. This requirement limits the permissible pH to about 10.6 at 25°C.

(2) The normal carbonate alkalinity should not exceed 120 ppm. Since the normal alkalinity is a function of the hydrogen-ion concentration and the total alkalinity, this requirement may be met by keeping the total alkalinity within the limits suggested below when the pH of the water is within the range given. These values apply to water at 25°C.

pH range	*Limit for total alkalinity (ppm. as $CaCO_3$)*
8.0 to 9.6	400
9.7	340
9.8	300
9.9	260
10.0	230
10.1	210
10.2	190
10.3	180
10.4	170
10.5 to 10.6	160

(3) *If excess alkalinity is produced by chemical treatment, the total alkalinity should not exceed the hardness by more than 35 ppm. (calculated as $CaCO_3$).*

4.3. *Recommended methods of analysis:* [8]

4.31. Ions with required limits of concentration.

Arsenic (As): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, p. 390; also "Colorimetric Microdetermination of Arsenic," Morris B. Jacobs and Jack Nagler. Industrial and Engineering Chemistry—Anal. Ed., **14**: 442 (1942).

Fluoride (F): *Standard Methods for the Examination of Water and Sewage,* current edition; also "Methods of Determining Fluorides," Committee Report, A. P. Black, Chairman. JOURNAL American Water Works Association, **33**: 1965–2017 (1941).

Lead (Pb): *Standard Methods for the Examination of Water and Sewage,* current edition.

Selenium (Se): Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, 1940, pp. 11 and 417; also Robinson, W. O., Dudley, H. C., Williams, K. T. and Byers, Horace G.; "The Determination of Selenium and Arsenic by Distillation." Industrial and Engineering Chemistry—Anal. Ed., **6**: 274 (1934).

Hexavalent Chromium: Standard Methods for the Examination of Water and Sewage, current edition.

4.32. Ions and substances with suggested limits of concentration.

Copper (Cu): *Standard Methods for the Examination of Water and Sewage,* current edition.

Iron (Fe) and *Manganese* (Mn): *Ibid.*

Magnesium (Mg): *Ibid.*

Zinc (Zn): *Ibid.*

Chloride (Cl): *Ibid.*

Sulfate (SO_4): *Ibid.*

Phenolic compounds: Ibid. With dibromquinonechlorimide as an indicator.

Total solids: Ibid.

Alkalinity: Ibid.

[8] For the chemical determinations referred to in this report, when given, the methods of analysis recommended by the Association of Official Agricultural Chemists are satisfactory and may be substituted for those recommended in the *Standard Methods for the Examination of Water and Sewage,* current edition, which are specifically cited.

Surplus Property Purchase Procedure

INSTRUCTIONS to eligible public health claimants for purchasing surplus property at a 40 per cent discount have been made available by the U.S. Public Health Service, through Robert C. Ayers, Director, War Property Distribution, Federal Security Agency.

The Federal Security Agency, through the U.S.P.H.S., a constituent unit, serves in an advisory capacity to the War Assets Corporation in the distribution of surplus property to eligible public health claimants. The new instructions replaced an interim procedure which expired February 16.

The bulk of goods offered for sale to public health claimants is "consumer goods" and "capital goods."

Sale of surplus foods will be handled by the U.S. Department of Agriculture.

To buy consumer goods, claimants should request notification of sales offerings suitable to their needs from the nearest regional WAC office for consumer goods, at which U.S.P.H.S. representatives are stationed.

To purchase capital goods, claimants may obtain lists of standardized items from the nearest of the 31 regional WAC offices handling such items as listed in the instructions. Information regarding availability of unlisted capital goods may be obtained by specifically describing the items needed.

All applications and purchase orders should be sent to the Public Health Specialist in Charge, U. S. Public Health Service, Office of Surplus Property Utilization, in care of the appropriate consumer goods office of the War Assets Corporation.

The purchase order, in quadruplicate, should be drawn to the specific WAC capital or consumer goods office which listed the property. The instructions give full information for making out the purchase order.

If, on the basis of eligibility and need, the discount is authorized, the U.S.P.H.S. representative will send the order directly to the disposal agency to be filled. In many instances, it may be advisable for the buyer to make an inspection or selection of property and present the approved order in person at the time of the sale. In that event, the approved order will be returned to the claimant at his request.

The complete instructions are reprinted below. Additional copies of the instructions may be obtained from the Office of Surplus Property Utilization, U. S. Public Health Service, Railroad Retirement Building, Washington 25, D.C., and from the U.S.P.H.S. representative in the WAC regional consumer goods office.

Instructions for Public Health Claimants

How to Order Surplus Property (Other Than Real Property) at a Discount

Applicants Eligible for a Discount

Surplus Property Administration Regulation 14 provides for a discount of 40 per cent on sales to eligible public health claimants. The discount is allowed from the "fair value" of the property ("fair value" is defined as the lowest price prevailing at any trade level at the time of the transaction). The following groups of claimants are eligible:

1. State, county and local health departments and units.

2. State, county and local sanitation departments and units (including these pub-

licly owned and operated services: water works supplying water to the community, sewerage systems, garbage and refuse disposal units).

3. Hospitals operated by (non-federal) governmental agencies.

4. Non-profit hospitals, clinics and public health research organizations.

5. Schools of nursing, medicine, public health, dentistry and pharmacy.

6. Miscellaneous non-profit groups organized primarily to promote the public health.

State, county and local health and sanitation agencies, and hospitals operated by (non-federal) governmental agencies (1, 2 and 3 above) should have no difficulty in determining their own eligibility. Non-profit institutions, certain types of schools, and miscellaneous groups organized primarily to promote the public health (4, 5 and 6 above) are eligible for the discount if they have been held tax-exempt under section 101 (6) of the United States Internal Revenue Code.

The U.S.P.H.S. maintains a list intended to include the names of all claimants eligible for a discount under Regulation 14. Since this list is a basis for approval, applicants in doubt as to their status should check with the nearest representative of the U.S.P.H.S., Office of Surplus Property Utilization, to be sure they are represented. Locations of these representatives are shown below.

How to Obtain Information About Available Surplus Property

Regional offices of the WAC, upon request, furnish lists of property available for sale. Public health claimants will be particularly concerned with two classifications of surplus: "consumer goods" and "capital goods." The WAC maintains separate offices for the disposal of these two groups of property.

The classifications "consumer goods" and "capital goods" are necessarily arbitrary in some instances. It may be generally said, however, that "consumer goods" include finished products ordinarily used by individuals or commercial establishments, as well as construction machinery, farm machinery and motor vehicles, and that "capital goods" include items used in industry and manufacture, such as machinery, machine tools, raw materials (except agricultural), semi-fabricated items, together with transportation and communication property.

Claimants who wish to buy "consumer goods" should request notification of offerings suitable to their needs from the appropriate disposal agency office given in the first list below. Those who intend to purchase items of "capital goods" may obtain lists of standardized items from the appropriate office in the second list below. Information regarding the availability of unlisted capital goods items may be obtained by making inquiry specifically describing the items needed.

Inquiries concerning availability of surplus foods should be addressed to the United States Department of Agriculture, Production and Marketing Administration (Attention: Surplus Property) Washington 25, D.C.

All requests for lists of available property should specify the particular classes of goods in which the applicant is interested.

In the territories and possessions listed below, the sale of all types of properties except aircraft, ships and maritime property, is handled by the Department of the Interior. Inquiries regarding the availability of surplus properties by claimants in such areas should be directed to the following offices:

For Hawaii: Dept. of the Interior, Surplus Property Office, Honolulu, T.H.

For Alaska: Dept. of the Interior, Surplus Property Office, Anchorage, Alaska.

For Puerto Rico and Virgin Islands: Dept. of the Interior, Surplus Property Office, San Juan, P.R.

Preparing an Order to Buy Surplus Property at a Discount

To buy "consumer goods" listed as available by the disposal agency, the

claimant uses his usual purchase order form. The order (*in quadruplicate*) should be drawn to the office of the disposal agency listing the property, should request only items that appear in such listing, and should be prepared according to conditions accompanying the offering by the disposal agency. On the body of the order, the buyer should state that "Funds are available for the purchase of these items at fair value less 40 per cent." The disposal agency will normally accept only a formal purchase order. In case of emergency, however, the disposal agency will accept a "letter of intent," indicating that the applicant is willing to purchase the specific items requested, to be followed at the earliest practicable date by the claimant's formal purchase order.

For the purchase of capital goods, the claimant's usual purchase order form (in quadruplicate) may be used as outlined above. However, the disposal agency will accept a "letter of intent" in lieu of the purchase order form. It is not essential that capital goods requested be contained in a published list of available property.

Preparing the Application for Discount

An application should be prepared (in duplicate) to accompany the claimant's order. It should be addressed to the Office of Surplus Property Utilization, United States Public Health Service, and should comprise the following parts:

1. A request that a 40 per cent discount be approved for the accompanying purchase order.

2. A statement as follows: "The applicant represents and warrants that: It is (an instrumentality) (a non-profit institution) as defined in SPA Regulation 14;* that the property ordered in the attached purchase document is required for its own use and to fill its own existing need for carrying on medical, public health or sanitation activity; that the property will not be resold within three (3) years of the date of the purchase without the consent in writing of the disposal agency."

3. A statement which will show the ways in which and the extent to which the public health will be benefited by the applicant's use of the property being ordered. This statement should show *how and to what extent the volume or quality of service will be increased and why the area served by the claimant needs such an increase.*

4. Signature and title of a responsible official.

Following the Order Through

Send or take all four copies of the order (regular purchase order form or "letter of intent") and both copies of the application to the appropriate representative of the Office of Surplus Property Utilitization, Public Health Service, for approval. If, on the basis of eligibility and need, the discount is authorized, the

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* Cross out either "an instrumentality" or "a non-profit institution," according to definitions as follows:

(1) "Instrumentality" as used herein refers to any instrumentality of a state, territory or possession of the United States, the District of Columbia, or any political subdivision thereof, as well as to such states and subdivisions themselves.

(2) "Non-profit institution" means any non-profit scientific, literary, educational, public health, public welfare, charitable or eleemosynary institution, organization or association, or any non-profit hospital or similar institution, organization or association, which has been held exempt from taxation under section 101 (6) of the Internal Revenue Code, or any non-profit volunteer fire company or co-operative hospital or similar institution which has been held exempt from taxation under section 101 (8) of the Internal Revenue Code.

(3) "Public health institution or instrumentality" means any hospital, board, agency, institution, organization or association which is organized for the primary purpose of carrying on medical, public health, or sanitational services in the public interest, or research to extend the knowledge in these fields, and which is a non-profit institution or an instrumentality.

U.S.P.H.S. representative will send the order directly to the disposal agency to be filled. In many instances, it may be advisable for the buyer to make an inspection or selection of property and present the approved order in person at the time of the sale. In that event, the approved order will be returned to the claimant at his request.

Terms of Sale

Terms of payment are prescribed in conditions of sale issued by the disposal agency to accompany offerings of property.

Addresses of U.S.P.H.S. Representatives and Consumer Goods Offices

The following list shows regional offices of the WAC at which representatives of the U.S.P.H.S., Office of Surplus Property Utilization, are located. This list should be used by public health claimants both to determine the nearest disposal agency office from which to obtain listings of available consumer goods and to locate the U.S.P.H.S. representative in their area.

1. 600 Washington St., Boston 11, Mass. (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.)
2. 61st Floor, Empire State Bldg., 350 Fifth Ave., New York 1, N.Y. (New York, New Jersey.)
3. 5th and Chestnut Streets, Philadelphia, Pa. (Pennsylvania, Delaware, Maryland, District of Columbia, Virginia.)
4. 704 Race St., Cincinnati 2, Ohio. (West Virginia, Ohio, Kentucky, Indiana.)
5. Room 300, 209 S. LaSalle St., Chicago 4, Ill. (Illinois, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota.)
6. Belle Isle Bldg., 105 Prior St., N.E., Atlanta 3, Ga. (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee.)
7. 609 Neil P. Anderson Bldg., Fort Worth 2, Tex. (Arkansas, Louisiana, Oklahoma, Texas.)
8. 2605 Walnut St., Kansas City 8, Mo. (Iowa, Missouri, Kansas, Nebraska.)
9. 7th Floor, Exchange Bldg., 1030 15th St., Denver 2, Colo. (New Mexico, Colorado, Wyoming, Utah.)
10. 30 Van Ness Ave., San Francisco, Calif. (California, Arizona, Nevada.)
11. 2005 Fifth Ave., Seattle 1, Wash. (Washington, Oregon, Idaho, Montana.)

Communications requesting lists of available consumer goods should be addressed to the Agency Manager, War Assets Corporation, at the appropriate office in the above list.

Communications concerning eligibility and orders for property at a discount should be sent to the Special Representative, U.S. Public Health Service, in care of the appropriate office of the War Assets Corporation in the above list.

However, for public health claimants located in Hawaii, Alaska, Puerto Rico or the Virgin Islands, purchase orders and applications should be sent to the representative of the Office of Surplus Property Utilization at the appropriate location as follows:

For Hawaii: U.S. Public Health Service Dist. No. 10, Honolulu, Hawaii.

For Alaska: U.S.P.H.S., c/o Territorial Dept. Health, Ketchikan, Alaska.

For Puerto Rico and the Virgin Islands: U.S. Public Health Service Dist. No. 6, San Juan 18, Puerto Rico.

Addresses of Disposal Agency Offices for Capital Goods

The following list shows regional offices of the WAC which supply lists of available capital and producers' goods.

Atlanta, Ga.—Ford Bldg.

Birmingham 3, Ala.—Jamison Bldg., 2105 3rd Ave. N.

Boston 9, Mass.—Sheraton Bldg., 10 Post Office Square.

Charlotte 2, N.C.—317 Tryon St.

Chicago 4, Ill.—208 S. LaSalle St.

Cleveland, Ohio—Newman-Stern Bldg.

Dallas 1, Tex.—301 Cotton Exchange Bldg.

Denver 2, Colo.—Boston Bldg.

Detroit, Mich.—Buhl Bldg.

Helena, Mont.—Power Block, P.O. Box 177.

Houston 2, Tex.—Rusk Bldg., 723 Main St.

Jacksonville 2, Fla.—Western Union Bldg., Laura & Duval Sts.

Kansas City 6, Mo.—Dierks Building, 1006 Grand Ave.

Little Rock, Ark.—Wallace Bldg., Markham & Maine Sts.

Los Angeles 14, Calif.—Pacific Mutual Bldg., 523 W. 6th.

Louisville 2, Ky.—Lincoln Bank Bldg., 421 W. Market St.

Minneapolis 1, Minn.—McKnight Bldg., 2nd Ave. S. & 5th St.

New Orleans, La.—7020 Franklin Ave.

Nashville 3, Tenn.—Consolidated-Vultee Plant.

New York 5, N.Y.—70 Pine St.

Oklahoma City, 2, Okla.—Cotton Exchange Bldg.

Omaha 2, Neb.—Woodmen of the World Bldg.

Philadelphia 2, Pa.—1528 Walnut St.

Portland, Ore.—310 S.W. 6th.

Richmond 19, Va.—Richmond Trust Bldg., 7th & Main Sts.

Saint Louis, Mo.—505 N. 7th St.

Salt Lake City, Utah—101 W. 2nd St.

San Antonio 5, Tex.—Transit Tower Bldg., S. Saint Mary St. at Billita St.

San Francisco, Calif.—Barneson Bldg., 256 Montgomery St.

Seattle 4, Wash.—Central Bldg.

Spokane, Wash.—Welch Bldg., 610 W. Maine Ave.

Report of the Publication Committee

Submitted to the A.W.W.A. Board of Directors, Jan. 14, 1946

1. The JOURNAL

a. Text Contents: During 1945, the JOURNAL contained 1,434 pages of papers and abstracts (exactly the same number as in 1944). It is planned to increase the Text Contents to 1,800 pp. in 1946. Included in 1945 were these reports:

(1) Report of the Committee on Water Works Practice

(2) Reports of the Committee on Survival and Retirement Experience With Water Works Facilities—Introductory Statement and 16 subsequent reports on individual plants

(3) Tentative Standard Specifications for Deep Wells—4A.1-T—1945

(4) Committee Report—Summary of 1945 Pension and Retirement Legislation

(5) Tentative Standard Specifications for Sulfate of Alumina—W1.1-T

The report of the Audit of Association funds for the year ending Dec. 31, 1944, was published in the March 1945 JOURNAL. The December issue included a report on the A.W.W.A. in 1945; listing of Papers Scheduled at Section Meetings; and the Table of Contents and Indexes for the year.

In addition to the items cited above, 134 articles were published. Of these, 78 articles were Section Meeting contributions and the remaining 56 were contributions from the field, WPB releases, and reports and statutes, etc., emanating from various governmental units.

b. Abstracts: A total of 111 pages of abstracts was published in 1945, these being derived chiefly from foreign publications.

c. Advertising: Actual space total of 1945 advertising was 631 pp., compared with 570 pp. in 1944, 539 pp. in 1943, and 468 pp. in 1942. The amount of space contracted for 1946 by Dec. 31, 1945, was 560 pp.; therefore about the same amount of space is anticipated for 1946 as was sold last year.

d. Total Pages: The total of the above cited, including the News of the Field and the information at the front of each issue, was 2,358 pp., compared with 2,430 pp., including the Membership Directory, in 1944.

e. Printing: Beginning in February 1944, the Association paid for composition, presswork, binding and mailing at a rate increased by 10 per cent over 1943.

In 1945, an average of 6,518 copies was printed monthly, compared with 6,188 in 1944. The printing order for January 1946 is 6,800 copies.

The total cost of JOURNAL printing and production in 1945 was $22,973.53, compared to $19,604.44 for 1944. Greater costs for drafting illustrations and greater typesetting costs for the extensive tabulations for the Survival and Retirement reports are the chief factors increasing the 1945 accounts.

f. Paper Stock: After V-J Day and the subsequent lifting of WPB con-

trols, paper supply has been as much or more a touch-and-go proposition. Some large magazine publishers have purchased entire paper mills and are converting those mills' entire output to the new owners' requirements, thereby further aggravating the difficulties of supply. Many paper consumers hope to get more paper in 1946 and the Association will seek a slightly increased amount. As matters now stand, the supplier of the past few years is nominally committed to "take care of" the JOURNAL, but apparently that will be at best a continuation of the present small-lot-at-a-time basis, which is more costly.

To the extra cost incurred by small-lot supplying has been added a further cost for emergency transportation, thus effectively increasing the cost of paper to 32 per cent over 1943.

2. 1946 Membership Directory

A biennial Membership Directory is planned for issuance this year along the lines of the 1942 Directory, which carried advertising. A description of it as an advertising medium went to all advertisers and prospects in November 1945.

3. Index to the JOURNAL

Of the 1881–1939 Index, 299 copies remain in stock after a 1945 sale of 34 copies, compared to 23 sold in 1944.

A 1940–44 Index was issued at a printing cost of $527.26 as Part II of the March 1945 JOURNAL. It is available separately at $1.00 per copy.

4. Standard Methods for the Examination of Water and Sewage

See the Report of the Water Works Practice Committee.

5. Manual of Water Works Accounting

In 1945, 31 copies of this text were sold by the A.W.W.A., compared to 41 copies in 1944.

6. Specifications

Few large-lot sales were made in 1945, but by year's end several inquiries indicated the increased use of A.W.W.A. standards to supersede wartime emergency standards and to tie in with manufacturers' promotional activities.

7. The Manual of Water Quality and Treatment

This text is now out of print. A revised text has been partially developed during 1945.

Respectfully submitted,
LINN H. ENSLOW, *Chairman*

Report of the Committee on Water Works Practice

Submitted to the A.W.W.A. Board of Directors, Jan. 14, 1946

THE standardization activities of the A.W.W.A., which are under the jurisdiction of the Committee on Water Works Practice, are herewith reviewed and recorded.

Water Works Practice Subcommittees

1. *Deep Wells and Deep Well Pumps.* This committee operates under the co-chairmanship of J. C. Harding and J. A. Carr, Harding having the development of the well specifications under his jurisdiction and Carr handling deep well pumps. Tentative Standard Specifications for Deep Wells were approved on Apr. 30, 1945, and published as a part of the September 1945 JOURNAL. No adverse comments have been filed. It is the intention to move these specifications forward to *standard* status as of May 1946 unless objections are filed prior to that time. Co-chairman Carr has prepared and circulated among the members of the committee three drafts of the proposed pump specifications. A fourth, probably the final draft, is now in preparation and will be available for discussion by the committee prior to the 1946 Conference.

2. *Watershed Protection and Maintenance.* This important committee is moving forward under the leadership of Prof. Earnest Boyce of the University of Michigan. Plans are under way for an open discussion of the work of the committee in a session during the 1946 Conference. Each subcommittee chairman, E. E. Minor, J. S. Longwell and L. S. Finch, will be responsible for the outline of the phases of the work assigned to him. It must be understood that this committee is not charged with the preparation of specifications, but with the development: first, of an understanding of the factors involved in watershed control and utilization; and, second, with an expression of the broad policy which appears to govern watershed forestation, erosion control and the public use of watershed lands and impounding reservoirs.

3. *Manual of Water Quality and Treatment.* Under the leadership of A. Clinton Decker, the preparation of the second edition of this important manual is making good progress. Mimeographed draft copies of each chapter have been prepared and sent to all collaborators. Much discussion has ensued and two chapters have already been rewritten. It appears likely that a session on policy matters related to the manual will be held during the 1946 Conference. It should be possible to place the text in the hands of the printer during 1946, but the completed book should not be anticipated before 1947.

4. *History of Water Purification.* All of the text of this monumental volume is now in the hands of the printer. Illustrative material is ready for use. Manpower lack, at the printer's plant as well as in the A.W.W.A. office, has made it impossible to press forward

with this book. The printer is now ready to expedite the work and the book will be ready for sale during 1946.

5. *Steel Pipe and Coating.* Chairman W. W. Hurlbut reports no revision of any specifications is in progress. The committee is engaged in assembly of material for the "Manual of Design and Installation of Steel Pipe."

6. *Reinforced Concrete Pipe.* In March 1943, "Tentative Emergency Specifications for Reinforced Concrete Pressure Pipe," designated 7B-T, were approved by the Board of Directors. These covered in a single document a number of types of concrete pressure pipe and served a useful purpose during the war years. They did not cover prestressed pipe, which has been extensively used only during the past two or three years.

Because of difficulty in combining a number of different types of concrete pipe in a single specification and possible confusion in the use of a specification covering many different types of pipe, it appears that separate specifications, each covering only one specific type, should be prepared to take the place of the combined emergency specification. For example, Designation 7B.1-T would cover *Standard* Reinforced Concrete Pipe With Steel Cylinder; and Designation 7B.2-T would cover *Prestressed* Reinforced Concrete Pipe With Steel Cylinder. Later, if there seemed to be a need for them, separate specifications could be prepared for other types of concrete pressure water pipe not included in the two aforementioned designations. It is, therefore, recommended that the committee be authorized to prepare individual specifications covering both standard reinforced concrete pipe with steel cylinder and prestressed reinforced concrete pipe with steel cylinder, and that when such specifications are approved by the Board, the emergency specifications now designated as 7B-T shall be withdrawn.

7. *Fire Hydrants.* The committee is active under the chairmanship of Roger W. Esty. Discussions have centered about characteristics of the hydrant stem, such as its strength and resistance to corrosion. The chairman hopes to have the revised text completed during 1946.

8. *Valves.* Under the chairmanship of F. M. Randlett, the committee has conducted a survey of valve performance and maintenance requirements. The chairman proposes to confer with his committee during the 1946 Conference and thereafter prepare a revision of the present specifications.

9. *Sluice Gates.* W. R. Conard, Chairman, is working with his committee in an attempt to formulate practical testing apparatus and procedure for testing sluice gates. It is the opinion of the committee that the tightness of sluice gates should be a detail of inspection procedure, but agreement concerning procedure has not been reached.

10. *Laying Cast-Iron Pipe.* The committee which was appointed to revise the current document operates under the co-chairmanship of C. K. Calvert and J. P. Schwada. Calvert is in charge of the sections relating to main sterilization and Schwada the sections relating to the mechanical aspects of pipe laying. Schwada reports progress.

The sections relating to sterilization have been completed for some months. With minor editing, these paragraphs could be adjusted so as to apply to sterilization of all types of main pipes used to convey potable water. Since the availability of this material is of prime importance it is recommended

that the text of "Recommended Procedure for Sterilizing Water Mains" be authorized as a separate document and put forward for the routine approval procedure.

11. *Distribution System Records.* This committee is inactive. The report made by the committee and published in 1940 has been widely used as a guide by military agencies during the war period. No suggestions have been made which indicate need for revision of the report. W. V. Weir, who acted as chairman of the committee, also represents the Association on A.S.A. Committee Z32 on Graphical Symbols. If any standard established by the A.S.A. Committee impinges upon or conflicts with the A.W.W.A. standards, Weir will promote accord.

During the year 1945, an investigation was made to ascertain whether any standards or practice documents had been developed to cover "Symbols for Utility Structures or Installations in Public Highways." No such material has been found to exist, except to a limited extent in an A.P.W.A. document. It would appear that city engineers and related authorities should recognize the need for a manual or report covering such matters. Whether this subject could properly and effectively be added to the work of the A.S.A. Committee Z32 or undertaken as a voluntary inter-association activity by the A.P.W.A., A.W.W.A., A.S.A., E.E.I. and others, merits careful consideration. The A.W.W.A. through its already completed report is in a position to place before such a committee or group a completed document to cover its own field. There is, of course, full desire on the part of the Committee on Water Works Practice to co-operate in the development of such a manual.

12. *Distribution System Safety.* Chairman Wm. E. Stanley has been in contact with the members of his committee in an effort to reactivate it. This is quite necessary, since the proposed U.S.P.H.S. Manual of Water Sanitation Practice poses some very important questions of policy within the field of water distribution. The chairman therefore proposes to reorganize his committee so as to bring into active work a group of individuals who are able to consider this subject intensively during the current year.

13. *Cross-Connections.* Chairman M. W. Cowles has prepared a draft of "Test Procedure for Double Check Valve Installations," which will be submitted to state sanitary engineers for review before it is offered as an A.W.W.A. document.

Because many organizations at federal, state and local official level, as well as voluntary associations, such as A.W.W.A., have become independently interested in the protection of water mains against backflow from customers' premises, serious confusion in terminology exists. It is hoped that the A.W.W.A. Committee on Cross-Connections can take leadership in developing a set of terms and definitions which will assure that public health officials, water works engineers, plumbers and equipment manufacturers use a common and understood set of terms in this important segment of sanitation practice.

14. *Fire Prevention and Protection.* This committee is inactive.

15. *Meters.* The committee, under the leadership of S. F. Newkirk, has completed the specifications for current and compound meters. Specifications for Fire Line Meters are in development. The specifications for Cold Water Meters—Displacement Type

have been held in tentative form since 1941 because of the interference of war restrictions upon compliance. Now that the wartime limitations have been removed, the Board should make these specifications *standard*.

16. *Service Line Materials.* This committee has been engaged in a compilation of dimensional and weight standards of materials suitable for use in water services. Its work was suspended during the war because of restrictions upon the use of materials. Now that the restrictions have been lifted and some new standards have been promulgated, the material developed by the committee will be revised and published, provided that the text is approved by the Board.

17. *Recommended Standard Threads for Underground Service Line Fittings.* W. W. Brush has organized the committee to handle this very important matter. On a general review committee there is at least one representative of each section. There is a small executive group which has the counsel of a mechanical engineer who is fully acquainted with brass foundry and machine shop practices. We can expect this committee to produce satisfactory standards for service line fittings during the current year.

18. *Recommended Design of Valve, Curb Stop and Meter Boxes and Covers.* Committee Chairman Frank C. Amsbary reports that a preliminary report for this project will be available at the time of the 1946 Conference.

19. *Electrolysis and Electrical Interference.* See Sec. 46.

20. *Valuation and Depreciation.* There have been no specific tasks undertaken by this committee during 1945. The related activities of the joint committee on "Survival and Retirement Experience" are discussed in Sec. 36.

21. *Radio Facilities for Water Works.* Following the hearings by the FCC, the Utility Group was assigned a series of channels for use in their operations. The report on this subject was published in the July 1945 JOURNAL. Since that time a special group has been in conference with engineers of the FCC developing Rules and Regulations for the Use of Radio by Public Utilities. This work is not complete. C. F. Meyerherm continues his contact with the other utility staff members in the New York area who are working on this matter. W. V. Weir, who acted as advisor on this subject, has, at his own request, been relieved of this assignment and Adolph Damiano of the Hackensack Water Company has been appointed to succeed him. Damiano's duties at the present time consist in participation in the work of the committee which is drawing up rules for the use of radio and bringing into the deliberations of the committee the experience of the water works distribution engineer.

22. A committee to consider the *Use of Water in Air-Conditioning* was authorized by the Board at its 1945 annual meeting. Because of the shortage of manpower and overload upon water works engineers it has not appeared desirable to initiate the work of this committee. The project will be established as soon as it appears possible for engineers to devote the time to the work.

23. The *Tentative Manual of Zeolite Test Procedures* has been subjected to no criticism. Unless objections to its content are filed before the 1946 Conference, recommendation will then be made that it advance to *standard* status.

24. *Capacities of Water Treatment Plants.* The chairman of this committee, Douglas Feben, has recommended that this project be suspended. This recommendation is based upon his opinion that a sufficient body of data does not yet exist upon which to base firm recommendations for short-term sedimentation or high-rate filtration. The chairman's recommendation will have to be acted upon by the Water Purification Division, which group supervises the committee's work.

25. *Filtering Materials.* The committee chairman, Richard Hazen, has returned to civilian activities and proposes to review, with his committee, recommendations which have been made for modification of the present tentative specifications for filtering material. The discussions should be concluded during 1946.

26. *Biological and Chemical Problems of Water Distribution Systems.* This committee has been inactive during the war. The chairman, Marsden Smith, proposes to put the project on active status during 1946. This is a very important matter, since certain thinking in the field of sanitation envisages the maintenance of chlorine residuals in water distribution mains of sufficient magnitude to disinfect polluting material which might accidentally enter the system at distant points. The evaluation of normal conditions in a water distribution system as well as the nature and frequency of disturbances are matters of great importance, meriting the most careful study by this committee and by the Association.

27. *Joint Administration of Water and Sewer Departments.* This committee of the Finance and Accounting Division, under the Chairmanship of L. N. Thompson, has been reorganized. A session devoted to the interests of the committee is planned for the 1946 Conference.

Joint Committees With Other Organizations

28. *Water and Sewage Examination.* The ninth edition of this important book is now being put into type by the printer, after the committee-developed material had been edited by Dr. G. F. Symons. The Board has approved the delegation of authority to accept this text for the A.W.W.A. to the Chairman of the Committee on Water Works Practice and the Secretary/Editor of the A.W.W.A.

29. *Boiler Feedwater Studies.* This inter-association committee has not been reactivated since the war's end.

30. *Co-ordinating Committee on Corrosion.* This inter-association committee had no meeting during 1945. Its scope and future activities are now being reviewed by a special subcommittee.

31. *Standard Form of Construction Contracts.* An attempt has been made to reactivate this committee, which, in 1940, under the leadership of the Associated General Contractors, had developed valuable revision material, but was compelled to suspend its work because of wartime activities. The A.G.C. is willing to renew the activity, but some of the associations formerly represented on the joint-committee now decline to participate. It is greatly to be desired that a Committee on Standard Form of Construction Contracts be activated, because the current standard needs revision.

32. *American Research Committee on Grounding.* The work of this committee has lapsed and its chairman has retired from active business.

33. The *"Glossary—Water and Sewage Control Engineering"* is now in the hands of the A.S.C.E. editorial staff and ready for the printer. Clinton Bogert, who edited the great mass of material which had been assembled, completed his work on Oct. 2, 1945. This publication will be distributed gratis to the members of the A.W.W.A. as well as to the members of the other co-operating organizations, the A.P.H.A., A.S.C.E. and F.S.W.A.

34. *Manual of Water Works Accounting.* This text is still available for purchase. No revision is planned.

35. *Field Welding of Steel Water Pipe.* This joint enterprise of the A.W.W.A. and A.W.S., under the chairmanship of W. W. Hurlbut, has been cleared by the committee. (The Tentative Standard is published in this issue of the JOURNAL.)

36. *Survival and Retirement Experience.* The reports from the various water works properties are being published from month to month in the JOURNAL. Space in the JOURNAL became available as a result of wartime cancellation of meetings. The large amount of tabular material in these reports has increased the cost of JOURNAL publication materially. It is planned to reprint from 1,500 to 2,000 copies of the reports in a permanent binding, so that this important collection of fundamental data will be available for reference by interested persons. This will be completed during 1946.

37. *Steel Standpipes and Elevated Tanks.* Chairman L. R. Howson and his committee are developing new sections of the document to cover painting. This will be an important addition to the text.

Committees on Which the A.W.W.A. Has Representation

38. *Wrought-Iron and Wrought-Steel Pipe.* This is a Bureau of Standards Committee and is inactive.

39. *Cast-Iron Pipe and Special Castings.* This is an A.S.A. Committee (A21) having the A.W.W.A., N.E.W.W.A., the A.G.A. and the A.S.T.M. as sponsors. Three specification documents have been completed by the committee and have been accepted as standard. The Specifications for Tar-Dip Coatings for Cast-Iron Pipe were accepted by the Board as *tentative* only in 1944. It has not been possible to obtain permission to print these specifications as tentative. It is not recommended that the specifications be accepted as *standard* by this Board simply to make the publication possible, since there is reason to doubt that the document has the technical value that would merit its being accepted as standard.

Committee A21 has in preparation Specifications for Cast-Iron Pipe Other Than Pit Cast and for special castings larger than 12 in. Neither document is ready for approval by the sponsors.

40. *Manhole Frames and Covers.* This A.S.A. Committee developed specifications which were published in 1941. No revisions or additions are in progress.

41. The A.S.A. Committee on *National Plumbing Code* is nearing the completion of its task. Prof. F. M. Dawson and Warren Scott represent the A.W.W.A. adequately in the work that this committee is doing.

42. *Pipe Threads.* The movement toward an international accord on dimensions, etc., between Canada, England and the United States has proceeded satisfactorily during the current

year. Definite agreement has been reached in many areas of discussion.

43. *Pipe Flanges and Fittings.* No report of work completed by this committee in 1945 is available.

44. *Pressure Piping.* Minor activities are in progress. There are no major projects to report.

45. *Wrought-Iron and Wrought-Steel Pipe and Tubing.* No activity recorded in 1945.

46. *National Electrical Code.* The Committee on Code revision held a week-long session in October 1945. Certain points of view presented by the A.W.W.A. representative on the Subcommittee on Grounding were not accepted. The action taken by the Code Committee appears to introduce new problems for the water works field. Attention is invited to pages 1298 and 1299 of the December 1945 JOURNAL, on which appears the record of an address presented by C. F. Meyerherm before the International Association of Electrical Inspectors on Oct. 22, 1945.

47. A.S.A. Committee G-8 on *Zinc Coating of Iron and Steel* was liquidated in December 1945. The A.S.T.M. Committee on the subject matter now assumes control of this activity. The A.S.A. Committee has lacked leadership for several years and has been inactive. It appears that zinc coating of iron and steel plate is increasingly displaying its lack of ability to protect material for domestic hot water tanks. A discussion of this problem is scheduled for the 1946 Conference.

48. *Letter Symbols.* This A.S.A. Committee is inactive.

49. *Sieves for Testing Purposes.* This A.S.A. Committee is inactive.

50. *Standardization of Graphical Symbols for Use on Drawings.* This A.S.A. Committee is quite active. The following documents were completed during 1945:

Electric Power and Control—Z32.3

Telephone, Telegraph and Radio Use—Z32.5

Electric Apparatus—Z32.12

In 1946, Symbols for Use on Drawings in Mechanical Engineering will be reviewed. W. V. Weir represents the A.W.W.A. on this Committee and thus maintains liaison for the A.W.W.A. Committee on Distribution System Records.

51. *Wrought-Iron and Steel Valves, etc.* This is a Bureau of Standards Committee and is inactive.

52. *Inspection of Welded Structures.* The report of this committee was published in the 1942 Welding Handbook. No activity is current.

53. *N.F.P.A. Committees.*

a. *Electrical Code Committee* activities are covered under 46 above.

b. *Forests.* This committee is inactive and has no projects in hand.

c. *Hydrants, Valves and Pipe Fittings.* No project has reached completion during the year.

d. *Public Water Supplies for Fire Protection.* This committee is inactive.

e. *Elevated Tanks.* This committee is inactive.

54. During 1945, a request was received from the A.S.M.E. Boiler Code Committee that the A.W.W.A. join in organizing a committee to standardize flanges for steel water pipe. This derived from the publication of the paper by Hill, Lewis and Easter entitled "Fabricated Steel Ring Flanges for Water Pipe Service for Low Pressures and Low Temperatures" in the A.W.W.A. JOURNAL, September 194 After an exchange of ideas with W. W. Hurlbut, Chairman of the A.W.W.A. Committee on Steel Pipe, it was agreed

to co-operate in the formation of the joint A.W.W.A.-A.S.M.E. Committee. The representatives are:

A.W.W.A.—R. E. Barnard, Martin Ettington, H. O. Hill, S. Logan Kerr, H. Arthur Price

A.S.M.E.—D. B. Rossheim, N. O. Smith-Peterson, E. O. Waters, D. B. Wesstrom, F. S. G. Williams.

The committee met in New York on Oct. 2, 1945, and outlined the work to be done. Since that time, the A.W.W.A. staff has carried on a survey of the attitude of consulting engineers, consumers and manufacturers in the water works field to see what acceptance might be developed for standardization either along the line of A.S.M.E. current standards or of the design outlined by Hill and his associates. The replies from this survey are now in the hands of the committee. The project is a meritorious one for which the Steel Pipe Committee deserves credit for developing initial interest. The results of the committee's deliberations are bound to be of value to all users of large diameter steel pipe.

Respectfully submitted,

MALCOM PIRNIE, *Chairman*
Committee on Water Works Practice

Report of the Audit of Association Funds for the Year Ending December 31, 1945

To the Members of the American Water Works Association:

The By-Laws require that the Secretary shall have made an annual audit of the books of the Association.

The records for 1945 have been examined by the staff of Louis D. Blum & Co. The complete record of that examination follows.

Reference may be made to past audits which appeared in the JOURNAL as follows: pp. 520–25, March 1938; pp. 570–74, March 1939; pp. 516–20, March 1940; pp. 774–78, April 1941; pp. 426–30, March 1942; pp. 338–42, March 1943; pp. 359–63, March 1944, and pp. 317–21, 1945.

There is also submitted a membership statement for 1945 and a comparative record for 1928–1945 inclusive.

Respectfully submitted,
HARRY E. JORDAN
Secretary

February 8, 1946

TO THE AMERICAN WATER WORKS ASSOCIATION:

We have examined the balance sheet of the American Water Works Association as of Dec. 31, 1945, and the statements of income and expenses and surplus for the year then ended, have reviewed the system of internal control and the accounting procedures of the Association and, without making a detailed audit of the transactions, have examined or tested accounting records of the Association and other supporting evidence by methods and to the extent we deemed appropriate. Our examination was made in accordance with generally accepted auditing standards applicable in the circumstances and included all procedures which we considered necessary.

In our opinion, the accompanying balance sheet and related statements of income and expenses and surplus present fairly the position of the American Water Works Association at Dec. 31, 1945, and the results of its operations for the year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

(Signed)
LOUIS D. BLUM & CO.
Certified Public Accountants

EXHIBIT A—Balance Sheet, December 31, 1945

Assets

Cash in Banks and on Hand		$33,002.50*
Accounts Receivable:		
Advertising	$3,003.75	
Reprints	9.00	
Other	51.19	3,063.94
Membership Dues		335.50
Accrued Interest on Bonds		369.13
Inventories:		
Paper stock	$2,142.05	
Type metal	492.27	
Cumulative Index (298 copies)	357.60	
Manual of Water Works Accounting (22 copies)	31.90	
Manual of Water Works Practice (11 copies)	44.00	
Sundry publications	595.80	
Membership certificates	28.38	
Fuller Memorial Award certificates	26.56	
Back issues—Journals—Vols. 1 to 37, inclusive (29,442 copies)	—†	
Back issues—Proceedings—1881 to 1913, inclusive (276 copies)	—†	3,718.56
Office Equipment: (Less depreciation)		3,898.63
Investments at Cost, including excess of redemption value of United States Savings Bonds over issue price—(Quoted market value Dec. 31, 1945, $99,557.20) per Schedule 1		99,896.51
1946 Convention Expense		207.84
Deposits		1,100.00
Total Assets		$145,592.61

Liabilities and Surplus

Accounts Payable	$ 427.13
Membership Dues—Advance Payments	16,804.20
Unearned Subscriptions to Journal	1,681.00
Reserve for Award Fund (McCord)	4.56
Reserve for Expenses of Carbon Research Committee	48.46
Surplus, Per Exhibit C	126,627.26
Total Liabilities and Surplus	$145,592.61

* Canadian funds in the Bank of Montreal as at Dec. 31, 1945, amounted to $6,422.09, which, if converted into currency at that date, would have resulted in a loss of approximately $594.04. Had this loss been recorded, the cash in banks and the surplus would have been decreased accordingly.

† Back issues of Journals and Proceedings are inventoried but no money values are assigned to them for balance sheet purposes inasmuch as the entire costs were charged off during the year of publication.

EXHIBIT A, SCHEDULE 1—INVESTMENTS—DECEMBER 31, 1945

Description	Interest Rate, %	Principal Amount	Cost	Quoted Market Value 12/31/1945
City of Los Angeles	3½	$2,000.00	$2,241.11	$ 2,520.00
Province of British Columbia	4½	1,000.00	1,000.00	1,110.00
Province of Ontario	4½	2,000.00	1,690.00	2,020.00
Province of Ontario	4	1,000.00	732.50	1,195.00
Canadian Victory Bonds	3	6,000.00	5,647.75	5,692.50
Canadian Victory Bonds	3	2,000.00	2,000.00	1,875.00
Canadian Victory Bonds	1¾	2,000.00	2,000.00	1,825.00
United States Certificate of Indebtedness—Series K	⅞	10,000.00	10,005.15	10,007.70
United States Savings Bonds—Series C	2.9*	7,000.00	5,250.00	6,580.00†
United States Savings Bonds—Series C	2.9*	10,000.00	7,500.00	8,800.00†
United States Savings Bonds—Series D	2.9*	10,000.00	7,500.00	8,700.00†
United States Savings Bonds—Series D	2.9*	10,000.00	7,500.00	8,500.00†
United States Savings Bonds—Series G	2½	10,000.00	10,000.00	9,470.00†
United States Savings Bonds—Series G	2½	2,000.00	2,000.00	1,902.00†
United States Savings Bonds—Series G	2½	5,000.00	5,000.00	4,780.00†
United States Savings Bonds—Series G	2½	10,000.00	10,000.00	9,780.00†
United States Savings Bonds—Series G	2½	2,000.00	2,000.00	1,956.00†
United States Savings Bonds—Series G	2½	10,000.00	10,000.00	9,880.00†
United States Savings Bonds—Series G	2½	3,000.00	3,000.00	2,964.00†
Excess of redemption value of United States Savings Bonds, Series C and D, over issue price			4,830.00	
			$99,896.51	$99,557.20

* Yield, if held to maturity. † Current redemption value. ‡ Redeemable at the amount shown on Apr. 1, 1948

EXHIBIT B—STATEMENT OF INCOME AND EXPENSES FOR YEAR ENDED DECEMBER 31, 1945

Operating Income:		
Annual dues	$56,600.06	
Advertising	38,712.50	
Subscriptions to Journal	4,113.17	
Water and Sewage Works Mfrs. Association	7,500.00	
Interest on investments	2,220.75*	
John M. Goodell Prize	75.00	
Miscellaneous interest income	24.61	
Total Operating Income		$109,246.09
Publication Income:		
Manual of Water Works Practice	$ 65.00	
Manual of Water Quality and Treatment	25.73	
Manual of Water Works Accounting	110.15	
Reprints	2,328.13	
Cumulative Index	55.50	
Membership certificates	47.60	
Proceedings and Journals	2,260.05	
Specifications:		
Miscellaneous	158.90	
Meters	80.15	
Cast-iron pipe	127.65	
Steel pipe	260.90	
Elevated steel tanks	89.88	
Repainting tanks	7.35	
Gate valves	13.60	
Fire hydrants	10.05	
Wells and well pumps	3.20	
Sluice gates	6.50	
Water conservation	65.69	
Total Publication Income		5,716.03
Total Income (carried forward)		$114,962.12

* Includes $880.00 increment in redemption value on United States Savings Bonds for the year 1945.

Total Income (brought forward)			$114,962.12
Operating Expenses:			
Directors' and Executive Committee Meetings:			
Travel expense	$ 5,336.17		
Stenographic expense	255.60		
Executive committee meetings	541.72	$ 6,133.49	
Administrative Expenses:			
Rent	4,100.00		
Office supplies and services	6,960.06		
Membership promotion	85.87		
Legal and auditing expense	951.47	12,097.40	
Administrative Salaries		35,292.70	
Committee Expense		956.07	
Division and Section Expense:			
Division expense	12.12		
Section—membership allotment	6,229.00		
Section—official travel	1,937.28		
Section—general expense	308.96		
Regional meetings	1,366.62	9,853.98	
Journal:			
Printing	18,909.91		
Production	3,937.87		
Paper	5,138.04		
Abstractors	191.69		
Index—1940–1944	522.26	28,699.77	
Convention:			
General		328.34	
Membership Dues in Other Associations		875.00	
John M. Goodell Prize		75.00	
Depreciation of Office Equipment		675.92	
Miscellaneous Expense		30.67	
Total Operating Expenses		$95,018.34	
Cost of Publications Sold:			
Manual of Water Quality and Treatment	$ 676.55		
Manual of Water Works Practice	56.00		
Manual of Water Works Accounting	45.85		
Reprints	1,639.74		
Cumulative Index	42.00		
History of Water Purification	364.09		
Membership certificates, including lettering and mailing	42.96		
Journals and Proceedings	202.46		
Specifications:			
Miscellaneous	35.87		
Meters	64.88		
Cast-iron pipe	183.35		
Steel pipe	189.73		
Elevated steel tanks	57.27		
Repainting tanks	7.46		
Gate valves	20.62		
Fire hydrants	14.52		
Sluice gates	1.92		
Wells and well pumps	48.25		
Water conservation	30.65		
Total Cost of Publications Sold		$3,724.17	
Development Expense—Research:			
Wartime activities		858.10	
Total Expenses			99,600.61
Net Income for the Year (Transferred to Exhibit C)			$15,361.51

EXHIBIT C—SURPLUS ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1945

Balance, Jan. 1, 1945	$111,265.75
Add: Net income for the year, per Exhibit B	15,361.51
Balance, Dec. 31, 1945, per Exhibit A	$126,627.26

Membership Statement—Year of 1945

	Active	Corporate	Associate	Honorary	Junior	Affiliate	Total
Total Members, Jan. 1, 1945	4597	510	255	29	19	75	5485
Changes in Membership Grades	2	—	—	3	−4	−1	—
	4599	510	255	32	15	74	5485
Gains:							
New Members During 1945	450	62	18	—	2	11	543
Reinstatements During 1945	55	—	1	—	—	—	56
	5104	572	274	32	17	85	6084
Losses:							
Resignations and Deaths	97	2	6	2	—	4	111
Dropped for Non-payment	210	14	7	—	1	3	235
Total Members, Dec. 31, 1945	4797	556	261	30	16	78	5738
Total Members, Jan. 1, 1945	4597	510	255	29	19	75	5485
Gain in Year of 1945	200	46	6	1	−3	3	253

Comparative Statement—Gains and Losses—Eighteen-Year Period

Year	New	Reinstated	Resignations and Deaths	Suspended for Non-payment of Dues	Gain or Loss	Total Members at End of Year
1928	203	36	99	126	+14	2456
1929	314	25	118	130	+91	2547
1930	501	39	122	134	+285	2831
1931	203	22	123	216	−114	2717
1932	117	22	169	297	−327	2390
1933	168	56	159	234	−169	2221
1934	271	66	86	122	+129	2350
1935	565	42	85	190	+332	2682
1936	311	53	104	218	+ 42	2724
1937	515	86	122	139	+340	3064
1938	520	59	144	140	+295	3359
1939	578	64	112	179	+351	3710
1940	514	58	113	212	+247	3957
1941	480	92	116	236	+220	4177
1942	570	59	132	233	+264	4441
1943	769	88	130	198	+529	4970
1944	734	92	140	171	+515	5485
1945	543	56	111	235	+253	5738

A.W.W.A. 7A.8-T
AWS D7.0-46T

American Water Works Association

Tentative

Standard Specifications

for

Field Welding of Steel Water Pipe Joints

American Water Works Association
American Welding Society

These "Tentative Standard Specifications for Field Welding of Steel Water Pipe Joints" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the construction in the particular locality concerned.

Approved by the Board of Directors of the A.W.W.A. on January 10, 1946, and by the Board of Directors of the American Welding Society, on October 30, 1945

COPYRIGHTED AS PART OF THE MARCH 1946 JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION

American Water Works Association
Incorporated
500 Fifth Avenue, New York 18, N. Y.

Prepared by

Water Works Practice Joint Subcommittee 7A

Personnel

WM. W. HURLBUT, *Chairman*

Representatives of A.W.W.A.	*Representatives of A.W.S.*
ROBERT B. DIEMER	H. C. BOARDMAN
G. W. HAMLIN	H. M. CHADWICK
ROBERT C. KENNEDY	M. ETTINGTON
L. G. LENHARDT	G. H. GARRETT
H. ARTHUR PRICE	H. O. HILL

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Tentative

Standard Specifications for Field Welding of Steel Water Pipe Joints

Section 8–1—General

Sec. 8–1.1—Scope

These tentative standard specifications cover field welding by the metal arc-welding process of steel water pipe manufactured in accordance with Specifications 7A.3, Electric Fusion Welded Steel Water Pipe of Sizes 30 Inches and Over, and Specifications 7A.4, Steel Water Pipe of Sizes Up to But Not Including 30 Inches, of the American Water Works Association. Such field welding covers welding of circumferential joints of pipe and other welding required in field fabrication and installation of specials and appurtenances. The maximum wall thickness of pipe to be welded under these specifications shall be $1\frac{1}{4}$ in.

Sec. 8–1.2—Definitions and Symbols

1.2.1—Welding terms employed in these specifications shall be interpreted according to the definitions given in the latest edition of *Definitions of Welding Terms and Master Chart of Welding Processes,* issued by the American Welding Society.

1.2.2—Symbols used on construction drawings shall conform to those shown in the latest edition of *Welding Symbols and Instructions for Their Use,* issued by the American Welding Society.

Section 8–2—Filler Metal

Electrodes shall conform to the latest revisions of the A.W.S.—A.S.T.M. Specifications for Iron and Steel Arc-Welding Electrodes, A.S.T.M. Standard Specifications A233, having the following Classifications: E6010, E6011, E6012, E6013, E6020 or E6030. The electrodes selected shall be suitable for the electric current characteristics and also for the position of welding.

Section 8–3—Equipment

The contractor's equipment for all welding and flame cutting shall be designed and maintained in such condition as to permit qualified welding operators to follow the procedure specifications (Sec. 8–5) and obtain the results prescribed in these specifications.

Section 8-4—Inspection

Sec. 8-4.1—General

All work performed under these specifications shall be rigidly inspected. Such inspection shall not relieve the contractor of his responsibility for performing work in accordance with these specifications. He shall notify the purchaser in advance of performing any work under these specifications in order that the purchaser may arrange for inspection.

The inspector may reject any work that is not performed in accordance with the procedure specifications and that does not comply with the requirements set forth in these specifications.

Sec. 8-4.2—Access and Facilities for Inspector

The inspector shall have free access to those parts of the plant that are involved with the performance of any work under these specifications. The contractor shall furnish the inspector reasonable facilities and space for inspection, testing and obtaining any information he desires respecting the character of material used and the progress and condition of the work.

Sec. 8-4.3—Inspectors

Inspectors shall be qualified by training and experience to inspect welding of the character specified in this document.

Section 8-5—Qualification of Welding Procedure and Testing of Welding Operators

Sec. 8-5.1—Test Results of Procedure Qualification

Welding procedures shall be qualified in accordance with the latest rules of the A.W.S. Standard Qualification Procedure except for the following modifying conditions.

5.1.1—*Butt Joints (Groove Welds)*

5.1.1.1. *Reduced-Section Tension Test:* The tensile strength shall be not less than 45,000 psi., based upon the gross area of the steel coupon adjacent to the joint.

5.1.1.2. *Free-Bend Test:* The elongation shall be not less than 20 per cent.

5.1.1.3. *Root-Bend Test:* This test shall be omitted.

5.1.1.4. *Sectional Segments:*

(**a**) In addition to the above, two sectional segments, cut with a trepanning tool or spherical saw or by flame cutting, shall be removed from the weld in the test plate. These segments will serve as a measure of the degree of penetration of the welded joint which has withstood the above tests. These segments should be retained for future comparison with segments removed during construction.

(**b**) In case the sectional segments made in the test materials do not satisfy the purchaser as a guide for penetration in material of other thicknesses to be used in the construction, the contractor shall make reduced-section-tension tests and take sectional segments from material of the thicknesses to be used in construction to serve as a comparison with segments removed during construction.

5.1.2—*Lap Joints (Fillet Welds)*

5.1.2.1. *Tension Test:*

(**a**) In lieu of the prescribed longitudinal or transverse shear tests, two tension tests of the joints shall be made for each thickness, using the thinnest

and the thickest material that will be used in the construction. The details of the joint shall be similar to those which will be used in the construction, including belling or joggling. The test specimen shall be machined on the edges to 1½-in. width.

(b) The tensile strength shall be not less than 45,000 psi., based upon the cross-sectional area of the steel coupon adjacent to the joint.

5.1.2.2. *Free-Bend Test:* The elongation shall be not less than 20 per cent.

5.1.2.3. *Sectional Segments:* In addition to the above, two sectional segments, cut with a trepanning tool or spherical saw or by flame cutting, shall be removed from the weld in the test plate. These segments will serve as a measure of the degree of penetration of the welded joint which has withstood the above tests. These segments should be retained for future comparison with segments removed during construction.

Sec. 8-5.2—Welding Operators

5.2.1—All welding operators assigned to apply metal arc-welding to pipe joints under these specifications shall have been tested under the American Welding Society "Standard Qualification Procedure." The contractor shall certify that such tests were performed in accordance with the above requirements.

5.2.2—The operator qualification tests herein specified shall be considered as remaining in effect indefinitely unless: (1) the welding operator has not been continuously employed by the contractor on similar work, using similar welding procedure, for a period of six months or more, or unless: (2) there is some specific reason to question an operator's ability.

5.2.3—The contractor shall maintain a record of each welding operator employed by him, showing the dates and results of qualification tests and the work-identification mark assigned to him and shall make such records available to the purchaser. Each welded seam shall be stenciled with the identification mark of the operator welding the seam.

Section 8-6—Joint Design

Sec. 8-6.1—General

Joints may be either lap joints or butt joints, depending upon design requirements.

Sec. 8-6.2—Butt Joints

6.2.1—Butt joints may be either single or double welded. They will be single welded unless otherwise specified by the purchaser in his request for bid. (Pipe less than 30-in. inside diameter should not be entered for inside welding.)

6.2.2—Single-welded butt joints may be welded from the outside of the pipe; in the case of large diameter pipe, especially that used in tunnels, the joints may be single welded from the inside.

Sec. 8-6.3—Lap Joints

6.3.1—Lap joints may be either single or double welded. They will be full-fillet, single welded unless otherwise specified by the purchaser in his request for bid. (Pipe less than 30-in. inside diameter should not be entered for inside welding.)

6.3.2—Single-welded lap joints shall be welded on the outside of the pipe; except in the case of large diameter pipe, especially that used in tunnels, the joints may be single welded from the inside.

Section 8-7—Welding Design Details

Sec. 8-7.1—Maximum Thickness of Material To Be Welded

7.1.1—Maximum thickness for single-welded lap joints shall be $\frac{1}{2}$ in.

7.1.2—Maximum thickness for double-welded lap joints and all butt joints shall be $1\frac{1}{4}$ in.

7.1.3—Maximum thickness to be welded under these specifications shall be $1\frac{1}{4}$ in.

Sec. 8-7.2—Minimum Laps for Lap Joints

The minimum length of lap for double-welded lap joints shall be five times the thickness of the pipe, with a minimum of $1\frac{1}{2}$ in. The minimum length of lap for single-welded lap joints shall be $1\frac{1}{2}$ in.

Sec. 8-7.3—Minimum Size of Seal Welds

Material $\frac{3}{16}$ in. and less in thickness shall have full-fillet welds. Material over $\frac{3}{16}$ in. in thickness shall have seal welds of size not less than one-third the thickness of the thinner member at the joint, with a minimum of $\frac{3}{16}$ in., or as specified by the purchaser.

Section 8-8—Welding Procedure Details

Sec. 8-8.1—General

All welds in the pipe and attachments shall be made in strict accordance with the qualified procedure.

Sec. 8-8.2—Preparation of Welding Surfaces

Surfaces to be welded shall be free from loose scale, slag, heavy rust, grease, paint, cement and any other foreign material except tightly adherent mill scale. A light film of linseed oil primer or spatter film compound may be disregarded. Joint surfaces shall be smooth, uniform and free from fins, tears and other defects which adversely affect proper welding. A light film of rust, adhering after wire brushing on cut or sheared edges that are to be welded, need not be removed.

Sec. 8-8.3—Weather Conditions

Welding shall not be performed when the temperature of the base metal is less than 0°F. unless chemical properties of the base metals are suitable and proper precautions are taken. Welding shall not be performed when surfaces are wet from rain, snow or ice, when rain or snow is falling on the surfaces to be welded, or during periods of high wind, unless the operator and the work are properly protected. At temperatures between 32° and 0°F., the surface within 3 in. of the point where the weld is to be started shall be heated to a temperature warm to the hand before the welding is started.

Sec. 8-8.4—Cleaning Between Passes

Each pass of weld metal on multi-pass welding shall be free of slag and other extraneous deposits before the next pass is applied.

Sec. 8-8.5—Tack Welds

Erection tack welds used in the assembly of joints need not be removed, provided that they are sound and the cover beads are thoroughly fused into the tack welds.

Sec. 8-8.6—Peening

Peening of weld layers or passes may be used to prevent undue distortion. Surface layers and the first pass in groove welds shall not be peened.

Peening, when required, shall be performed with light blows of a hammer, using a blunt-nosed tool.

Sec. 8–8.7—Weld Contour

8.7.1—The surface pass on groove welds shall be substantially central to the seam, and all surface passes shall be reasonably smooth and free from depressions.

8.7.2—Fillet welds shall be obtained with a minimum cutting back of the outside pipe. The throat of a full-fillet weld shall be not less than 0.707 times the thickness of the pipe. Excess cutting back is a defect and shall be repaired. To facilitate inspection, the contractor may be required to apply punch marks at each joint a distance back on the outside plate at intervals around the circumference.

8.7.3—Undercutting of the base metal in pipe adjoining the weld is a defect and shall be repaired if it exceeds the amount given in Sec. 8–9.5.6.

8.7.4—All craters shall be filled to the full cross-section of the weld.

Sec. 8–8.8—Weld Reinforcement

On butt joints, no part of the finished surface in the area of fusion shall lie below the surface of the adjoining pipe. The weld reinforcement shall be not more than $\frac{1}{16}$ in. above the surface.

Sec. 8–8.9—Chipping and Gas Gouging of Welds

Any chipping at the root of welds and chipping of welds to remove defects shall be performed with a round-nosed tool or by gas gouging.

Sec. 8–8.10—Matching Butt Joints

Butt joints shall be accurately aligned and retained in position during the welding operation so that in the finished joint the pipe shall not project beyond its adjoining pipe by more than 20 per cent of the pipe thickness, with a maximum of $\frac{1}{8}$ in.

Section 8–9—Stipulation for Testing Welded Pipe Joints by Sectioning Methods

Sec. 8–9.1—Sectional Specimens

9.1.1—The welded pipe joints may be tested by sectioning methods as outlined herein.

9.1.2—Sectional specimens are segments cut from the welded joints with a cylindrical cutting tool or spherical saw or by flame cutting, which removes a portion of the welded joint and of the pipe bounding the welded joint and exposes thereon two full cross-sections of the welded joint. Specimens cut by a cylindrical cutting tool (trepanning saw) or by flame cutting are called "trepanned" specimens. Segments cut with a spherical saw are called "spherical" segments.

9.1.3—One segment shall be cut from the first completed joint welded by each operator. Thereafter, segments may be cut from joints which, in the opinion of the inspector, may be defective.

Sec. 8–9.2—Taking of Specimens

9.2.1—In the interest of preventing locked-up stresses due to rewelding, both the contractor and the inspector shall endeavor to control, as much as possible, the welding procedure, so that the necessity of making destructive tests by removing sections from the welded seam can be held to a minimum.

9.2.2—Test specimens shall be taken as the work progresses and as soon as

practicable after a questionable weld has been made, and, if possible, before the contractor's men and equipment are moved from that particular vicinity. The location for cutting out the test specimen is to be determined by the inspector.

Sec. 8–9.3—Size of Specimens

The specimens shall be removed on the center of the weld and shall be of such a size and removed in such a manner that at least $\frac{1}{16}$ in. of base metal at each side of the weld will be removed with each specimen. No specimen shall be less than $\frac{1}{2}$ in. in dimension at right angle to the axis of the weld.

Sec. 8–9.4—Preparation of Specimens

9.4.1—Specimens cut by the spherical saw are boat-shaped. Circular sections cut by a circular cutting tool or by flame cutting may be sawed in two, making the saw cut at right angle to the axis of the weld, before further preparation for inspection.

9.4.2—Specimens shall be etched for inspection by any of the following methods:

9.4.2.1. Without requiring any finishing or other preparation, place in boiling 50 per cent solution of muriatic (hydrochloric) acid until there is a clear definition of the structure of the weld. This will require approximately one-half hour.

9.4.2.2. Grind and smooth segments with emery wheel or file and emery paper and then etch by treating with a solution of 1 part ammonium persulfate (solid) and 9 parts of water by weight. The solution should be used at room temperature and should be applied by rubbing vigorously the surfaces to be etched with a piece of cotton kept saturated with the solution. The etching process should be continued until there is a clear definition of the structure of the weld.

9.4.2.3. Grind and smooth segments with emery wheel or file and emery paper and then etch by treating with a solution of 1 part of powdered iodine (solid form), 2 parts of powdered potassium iodide and 10 parts of water, all by weight. The solution should be used at room temperature and should be brushed on the surface to be etched until there is a clear definition of the structure of the weld.

9.4.3—To preserve the appearance of the etched segments, they should be washed in clear water after etching, then the excess water removed and the segment immersed in ethyl alcohol and dried. The etched surfaces may then be preserved by coating with a thin clear lacquer.

Sec. 8–9.5—Inspection of Specimens

9.5.1—The etched segments shall be examined to ascertain the extent of weld defects, such as gas pockets, slag inclusions, lack of fusion, undercutting and cracks.

9.5.2—For all welds, the etched surfaces of the segments shall show sufficient fusion between the weld metal and the base metal to meet the test requirements of Sec. 8–5. There shall be no cracks in any weld.

9.5.3—In either butt joints or lap joints, slag inclusion is permissible where it occurs between layers of the weld, is substantially parallel to the face of the weld and is equal to not more than one-half the width of the weld metal measured in a direction parallel to the face of the weld and when its greatest dimension measured in a direction perpendicular to the face of the weld does not exceed 10 per cent of the throat.

9.5.4—Gas pockets are permissible that do not exceed $\frac{1}{16}$ in. in the great-

est dimension and when there are no more than six gas pockets of this maximum size per square inch of the weld metal or where the combined areas of a greater number of pockets do not exceed 0.02 sq.in. per sq.in. (2 per cent) of weld metal.

9.5.5—For butt joints (groove welds), penetration is required only within the limits established by Sec. 8-5.1.1. A maximum undercut of $\frac{1}{32}$ in. at each edge of the weld may be permitted, provided that the undercut shall not reduce the thickness of the joint below the requirements of Sec. 8-5.1.1.

9.5.6—For lap joints (fillet welds), an undercut $\frac{1}{32}$ in. deep, measured on either leg, and lack of penetration at the root of $\frac{1}{32}$ in., measured along either leg or the throat, shall be the maximum permitted, provided that the size of the weld is increased to compensate for the deficiency in root penetration.

9.5.7—Where a defective segment is located, additional segments shall be cut from the same operator's work, 2 ft. on each side of the defective segment, wherever the joint length will permit. If additional defective segments are found, then more segments shall be cut at intervals of 2 ft. on the same operator's work until the limit of the defective welding has been definitely established; or the contractor may proceed to replace all of the welding done by that operator without cutting out additional segments.

Sec. 8-9.6—Repair of Openings Made by Cutting Out Specimens

Weld metal and base metal adjacent to holes made by cutting out specimens shall be enlarged and reshaped by chipping or gouging so that the cavity or hole may be properly repaired by welding.

Sec. 8-9.7—Record of Segments

The segments, upon removal, shall be properly stamped or tagged for identification, and, after etching, kept in proper containers with a record of their place of removal as well as the name of the welding operator who performed the welding. The inspector shall make a record of the examination of all segments. At the option of the purchaser the segments may be retained or discarded at the completion of the work.

Section 8-10—Repair of Welds

Sec. 8-10.1—Repair of Leaks

Leaks in welds occurring when the pipeline is under hydrostatic or other tests shall be repaired by removing the defective material which caused the leak and rewelding. No leaks shall be repaired by mechanical calking.

Sec. 8-10.2—Repair of Defective Welds

10.2.1—Defects in welds, or defective welds, shall be removed by chipping or by gas gouging from one or both sides of the joint as required. The chipped out places shall then be rewelded. Only sufficient cutting out of defective joints as is necessary to correct the defects is to be required. Replacement welds in joints may be checked by repeating the original test procedure.

10.2.2—When the base metal of a fillet weld is cut back excessively, as described in Sec. 8-8.7.2, or the throat of the weld is less than the minimum specified in Secs. 8-8.7.2 and 8-9.5.6, then the defect shall be repaired by adding additional weld metal.

APPENDIX

Section A8-1—Temperature Stresses

Precautions must be taken to reduce stresses in pipe joints caused by expansion of the pipeline due to temperature. The following method has been used satisfactorily:

Provide a slip-joint with 4-in. longitudinal adjustment, in addition to the minimum lap joint requirements, at intervals of about 300 to 500 ft. Set the slip-joints so that they will be in the approximate closed position at the highest temperature prevailing during the laying operations. Weld all the joints except the slip-joints. Backfill the pipe completely except at each slip-joint. If there is to be a hydrostatic test, omit the backfill from all joints. Weld the slip-joints at the coolest hour of the early morning. Perform the hydrostatic test, if required. Complete the backfill.

Section A8-2—Test for Leaks

1.2.1—Tests for leaks on completed butt joints and single-welded lap joints are usually made by testing the line hydrostatically.

1.2.2—Tests for leaks on completed double-welded lap joints may be made after completion of the welds which will permit immediate back-filling. Such test, which may be specified by the purchaser, is as follows:

Drill and tap $\frac{1}{8}$-in. diameter hole for standard piping in the lap or bell end of the pipe (this should be done at the fabricating shop). Apply 100 psi. pressure of air or other satisfactory gas into the connection between the two fillet welds. Paint inside and outside of the joint with soap suds. Mark any leaks indicated by the escaping gas-forming bubbles. Repair leaks and retest. Close the $\frac{1}{8}$-in. openings with pipe plugs.

Section A8-3—Return Welds (Boxing)

When applying the last pass of welding to the circumferential seams, when longitudinal seams are encountered, carry this pass along the longitudinal seam for about 2 in. in order to prevent leaks at these weld intersections.

St. Paul, Minnesota—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1941

THE St. Paul Water Department is the operating medium of the municipal water system serving the city of St. Paul, the adjacent city of West St. Paul, a portion of the city of South St. Paul and several rural communities known as Rosetown, New Canada and a portion of Mendota Township.

St. Paul, the capital city of Minnesota, is located on the northeastern bank of the Mississippi River at about the head of river navigation. Besides being the capital city, St. Paul is the hub for the great railroad systems of the Northwest and has become the commercial and industrial center for that section of the country. It has some of the largest wholesale houses in the country dealing in farm products, groceries, drugs and other commodities. The great stock yards, slaughtering and packing houses of South St. Paul are among the country's largest establishments in that line.

At the time of this study the estimated population of the city proper was 290,000, with some 300,000 being served by the department, supplied through 62,143 active service connections of which 59,657 were metered accounts. The consumption for the year (1941) was 8,904 mil.gal. or an average of 24.4 mgd. This was equivalent to 360 gpd. per tap or 84 gpd. per person, as measured by delivery to the system.

Development of the Existing System

The first plant which supplied water to the city was built by a private company, the St. Paul Water Company, in 1869–70, operating under a state charter granted in 1857. This first plant did not have any reservoirs or pumps and but a few miles of mains. It was not long before the city outgrew the financial ability of the company to keep pace and the citizens decided to secure and operate their own system.

In 1881 the state legislature authorized the city to purchase the private company. The purchase was completed in August 1882 and a Board of Water Commissioners was created to govern the new department. From 1882 to 1914 the members of the board were appointed from representative citizenry; since the new city charter was adopted in 1914 the board has been composed ex officio of the Commissioners of Public Utilities, Public Works and Finance.

The original supply was from Lake Phalen, a small lake located north of the city, and the distribution, entirely by gravity, was through a few miles of cement-covered sheet iron pipe, earthenware pipe and a small amount of cast iron. Upon purchase of the original plant by the city, the board immediately started an expansion program. This program selected as the source of supply a chain of five prin-

TABLE 1

SUMMARY OF MAINS
ST. PAUL, MINNESOTA

Size, *in.*	Kind	No. of Feet Installed	No. of Feet Identified	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
4	Cast-iron unlined	110,076	87,409	2.6	16,630	17.4	70,779	2.1	1882	46.7
6		2,218,762	2,180,386	64.2	44,136	46.2	2,136,250	64.7	1882	33.4
8		174,828	174,828	5.1	2,980	3.1	171,848	5.2	1895	17.7
12		395,635	395,635	11.7	5,949	6.2	389,686	11.8	1883	36.9
16		263,902	263,902	7.8	8,054	8.4	255,848	7.7	1883	37.6
20		66,490	66,490	2.0	2,831	3.0	63,659	1.9	1884	42.8
24		31,992	31,992	0.9	249	0.3	31,743	1.0	1883	37.1
30		61,678	61,678	1.8	0	0.0	61,678	1.9	1884	35.1
36		20,653	20,653	0.6	685	0.7	19,968	0.6	1884	36.2
42		11,237	11,237	0.3	0	0.0	11,237	0.3	1923	18.5
6	Cast-iron (Universal)	62,638	62,638	1.8	0	0.0	62,638	1.9	1931	4.4
8		4,700	4,700	0.1	0	0.0	4,700	0.1	1934	7.5
12		696	696	0.0	0	0.0	696	0.0	1939	2.4
4	Cement	9,814	888	0.0	888	0.9	0	0.0	1882	—
6		5,846	0	0.0	0	0.0	0	0.0	—	—
12		3,640	0	0.0	0	0.0	0	0.0	—	—
16		29,359	6,000	0.2	6,000	6.3	0	0.0	1887	—
24		14,024	7,024	0.2	7,024	7.4	0	0.0	1885	—
3	Galvanized iron	1,831	1,831	0.1	100	0.1	1,731	0.1	1921	16.4
20	Steel	8,409	8,409	0.3	0	0.0	8,409	0.3	1938	3.3
24		2,621	2,621	0.1	0	0.0	2,621	0.1	1938	3.5
30		8,014	8,014	0.2	0	0.0	8,014	0.3	1938	3.5
TOTAL		3,506,845	3,397,031	100.0	95,526	100.0	3,301,505	100.0		33.0
Percentage of Total			100.00		2.81		97.19			
Average Size, *in.*			8.87		9.54		8.85			

Mortality Survival Ratios

Size, *in.*	Kind	Number of Feet	Period Covered, *yr.*	Percentage
4	Cast-iron unlined	87,409	59.5	79.636
6		2,243,024	59.5	91.977
8		179,528	46.5	97.931
12		396,331	58.5	98.281
Over 12		455,952	58.5	95.816
4–24	Cement	13,912	35.5	0.000
3	Galvanized iron	1,831	20.5	93.594
20–30	Steel	19,044	3.5	100.000
TOTAL		3,397,031		

TABLE 2

Summary of Meters
St. Paul, Minnesota

Size, *in.*	Kind	Number Purchased	Number Identified Installed	Number Retired	Number in Service	Average Age, *yr.*
⅝	Disc	62,603	58,584	6,756	51,828	19.9
¾	Disc	4,745	4,476	388	4,088	11.3
1	Disc	3,437	3,144	260	2,884	13.6
1¼	Disc	261	256	1	255	27.3
1½	Disc	1,221	1,081	179	902	15.9
2	Disc	607	500	75	425	22.1
3	Disc	11	11	7	4	25.2
4	Disc	4	4	4	0	—
2	Compound	50	50	0	50	4.8
3	Compound	174	173	53	120	8.1
4	Compound	119	118	43	75	8.0
6	Compound	44	44	18	26	10.8
8	Compound	2	2	0	2	5.5
3	Turbine	19	19	7	12	12.7
4	Turbine	10	10	3	7	19.5
6	Turbine	13	13	2	11	17.3
8	Turbine	1	1	0	1	24.5
Total		73,321	68,486	7,796	60,690	19.0
Percentage of Total			100.00	11.38	88.62	

Mortality Survival Ratios

Size, *in.*	Kind	Number	Length of Record, *yr.*	Percentage
⅝	Disc	58,584	43.5	15.163
¾–4	Disc	9,472	38.5	16.243
2–8	Other	430	27.5	11.777
Total		68,486		

Unidentified Meters

Size, *in.*	Kind	No Record	Stolen	Frozen	Burned	Sold	Total
⅝	Disc	3,750	161	48	30	30	4,019
¾	Disc	260	7	1	0	1	269
1	Disc	276	6	3	0	8	293
1¼	Disc	0	0	0	0	5	5
1½	Disc	125	1	12	0	2	140
2	Disc	93	4	7	0	3	107
3	Compound	0	0	1	0	0	1
4	Compound	0	0	1	0	0	1
Total		4,504	179	73	30	49	4,835

TABLE 3

CAUSES OF RETIREMENT OF CAST-IRON MAINS
ST. PAUL, MINNESOTA

Cause of Retirement	Size			
	4-in.	6-in.	8-in.	12-in.
	Feet Retired			
Inadequate	5,982	12,846		
Replaced	1,326	7,420		
Abandoned	5,428	4,130		
Market construction	821			
Houses moved	364			
Street changes	209	2,598	300	
Sewer construction			100	175
Taken up and relaid		706		
Railroad tank moved				47
Not known	2,500	16,436	2,580	5,727
TOTAL	16,630	44,136	2,980	5,949
Salvaged		1,394		

Cause of Retirement	Size			
	16-in.	20-in.	24-in.	36-in.
	Feet Retired			
Depot construction	720			
Bridge construction	1,940			
River improvement	1,089			
Reservoir construction		60	70	
Replaced	661		154	
Not known	3,644	2,771	25	685
TOTAL	8,054	2,831	249	685
Salvaged	3,123			

cipal lakes lying farther north of the city. The supply was augmented from time to time by proceeding further with diversion from other lakes and proved sufficient until 1920. The original supply from Lake Phalen was not abandoned until 1913.

In 1920 it became apparent the supply was becoming insufficient to meet the rapidly increasing demands. In 1922 the first filtration units were installed and in 1925 a conduit was installed from the Mississippi River to supply the additional amount of water required.

Again in 1936 it was apparent that the existing plant would not be sufficient to supply the growing demand

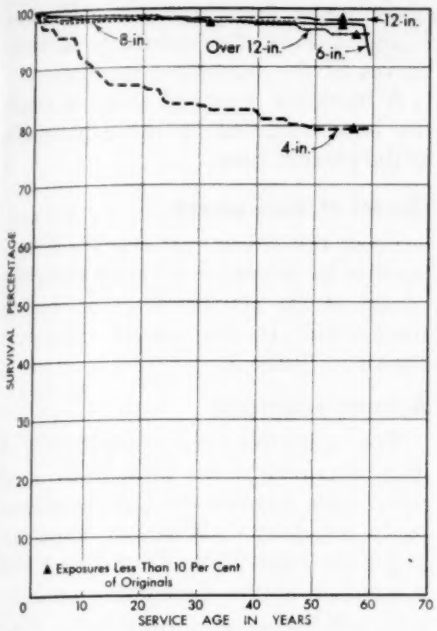

FIG. 1. Mortality Survival Curve—4–42-in. Cast-Iron Unlined Mains—St. Paul, Minnesota

BASE: Feet	SURVIVAL: 1882–1941	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	87,409	16,630
6	2,243,024	44,136
8	179,528	2,980
12	396,331	5,949
Over 12	455,952	11,819

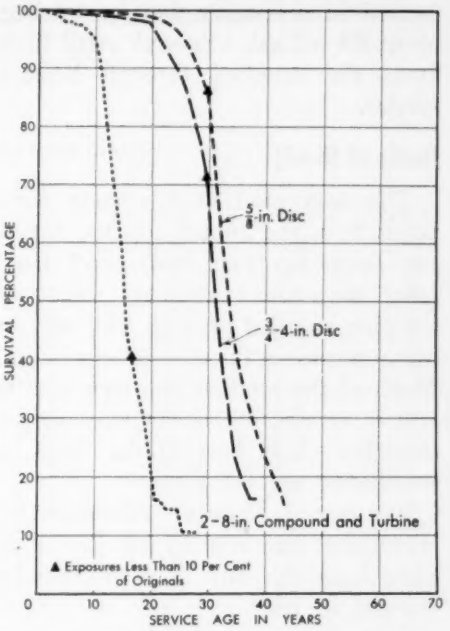

FIG. 2. Mortality Survival Curve—⅝–8-in. Meters—St. Paul, Minnesota

BASE: Unit		SURVIVAL: 1898–1941	
SIZE	KIND	EXPOSURES	RETIREMENTS
in.		*Units*	*Units*
⅝	Disc	58,584	6,756
¾–4	Disc	9,472	914
2–8	Compound and Turbine	430	126

and in 1937–40 extensions to the plant were made, including the addition of a softening plant, which brought the total capacity to 70 mgd.

Lakes Vadnais, Pleasant, Otter, Charles and Sucker form the principal impounding reservoirs of the present water supply system. The Centerville Lake system, consisting of four principal lakes, forms a second source which is pumped to the Vadnais reservoir system. As a third, and reserve source of supply, water from Otter and Bald Eagle Lake is diverted by gravity into the Vadnais system. The Mississippi River near Fridley, several miles north of Minneapolis, forms one of the principal sources at the present time, being pumped through a 60-in. conduit to Charles Lake of the Vadnais system.

The filtration plant has a nominal capacity of 70 mgd. The purification works settle, soften, filter and sterilize all water now used. The main pumping station, the McCarron Pumping Station, adjacent to the purification works, pumps to three services, the low, the Dale and Snelling high services. All have considerable storage

located in reservoirs therein, totaling about 65 mil.gal. Several small high areas are supplied through booster service.

Basis of Study

The data used in the study were taken from the annual reports, which are complete from 1882, and from other department records. Most of the pipe installed prior to 1882 was in active service at the date of acquisition. Much of the original cast-iron pipe is still in service but is not used in the mortality study because the dates of installation are not known.

The records of meter and service installations and retirements are complete from the date of acquisition by the city in 1882.

Mortality Survival Study

Mortality survival studies were made of mains and meters. Table 1 is a summary of the distribution pipe installed and retired as well as other pertinent data. Table 2 is a summary of the meter records studies. Figures 1 and 2 show the mortality survival curves of the respective facilities.

A mortality study of services could not be carried out by the department at the present time.

Causes of Retirement

From the old annual reports it was possible to determine in many cases the causes of the retirements. So far as these could be determined, they are shown in Table 3.

Acknowledgments

The collection and compilation of data pertaining to the study in St. Paul were made possible through the efforts of the late John C. Flanagan, Registrar of the St. Paul Water Department and a member of the Committee on Survival and Retirement Experience With Water Works Facilities. The research and tabulation were carried on by the regular staff of the Engineering Department under the encouragement of the Board of Water Commissioners and the personal supervision of Leonard N. Thompson, General Manager.

Summary of Installations and Retirements
St. Paul, Minnesota

MAINS

4-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1882	742	738	4
1883	4,494	925	3,569
1884	2,470	2,470	0
1885	9,142	7,109	2,033
1886	9,069	5,069	4,000
1887	10,922	5,323	5,599
1888	7,932	7,932	0
1889	10,661	10,294	367
1890	5,927	5,563	364
1891	2,072	2,072	0
1892	1,225	1,211	14
1893	5,019	5,019	0
1894	1,179	1,179	0
1895	920	920	0
1896	412	108	304
1897	387	387	0
1898	264	260	4
1900	310	310	0
1902	326	326	0
1903	636	636	0
1906	289	289	0
1908	1,002	1,002	0
1910	250	250	0
1911	294	294	0
1912	739	530	209
1913	607	607	0
1914	735	735	0
1915	137	137	0
1919	235	235	0
1920	324	324	0
1921	1,768	1,768	0
1922	670	670	0
1923	1,350	1,350	0
1924	946	783	163
1927	287	287	0
1929	54	54	0
1930	993	993	0
1932	210	210	0
1933	1,447	1,447	0
1936	834	834	0
1937	129	129	0
1941	0	0	0
Subtotal	87,409	70,779	16,630
Unknown	22,667	10,701	11,966
Total	110,076	81,480	28,596

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1882	4	1897				
1883	1,366	1887	770	1895	550	1896
	397	1897	486	1903		
1885	370	1895	14	1897	392	1909
	50	1913	304	1925	658	1930
	245	1932				
1886	1,893	1887	523	1895	1,030	1897
	554	1917				
1887	526	1887	3,489	1895	12	1897
1887	1,332	1910	240	1936		
1889	367	1929				
1890	364	1930				
1892	14	1897				
1896	192	1925	112	1936		
1898	4	1898				
1912	209	1935				
1924	163	1931				

6-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1882	14,682	5,870	8,812
1883	20,299	16,898	3,401
1884	27,187	21,873	5,314
1885	76,807	72,722	4,085
1886	72,249	64,084	8,165
1887	88,185	85,494	2,691

6-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet		
	Installed	In Service	Retired
1888	87,178	84,344	2,834
1889	109,157	108,219	938
1890	106,344	105,594	750
1891	23,799	23,799	0
1892	43,173	43,173	0
1893	29,322	29,322	0
1894	30,674	30,674	0
1895	24,781	24,275	506
1896	7,835	7,835	0
1897	11,192	11,192	0
1898	12,388	12,388	0
1899	13,216	13,216	0
1900	17,305	17,305	0
1901	15,322	15,322	0
1902	18,463	18,463	0
1903	26,516	26,516	0
1904	22,417	22,417	0
1905	22,255	21,775	480
1906	37,904	36,600	1,304
1907	52,115	50,851	1,264
1908	52,661	52,661	0
1909	60,433	60,381	52
1910	50,823	50,823	0
1911	41,332	41,332	0
1912	39,439	39,439	0
1913	44,314	43,682	632
1914	63,869	63,869	0
1915	69,369	69,293	76
1916	56,764	56,764	0
1917	42,224	42,224	0
1918	41,405	41,405	0
1919	27,440	26,262	1,178
1920	32,024	32,024	0
1921	43,965	43,965	0
1922	50,490	50,490	0
1923	57,310	56,446	864
1924	73,893	73,893	0
1925	52,094	51,661	433
1926	43,346	43,346	0
1927	57,928	57,928	0
1928	42,322	42,290	32
1929	34,636	34,636	0
1930	32,414	32,089	325
1931	7,911	7,911	0
1932	1,771	1,771	0
1933	1,884	1,884	0
1934	1,894	1,894	0
1935	1,689	1,689	0
1936	9,436	9,436	0
1937	6,668	6,668	0
1938	3,390	3,390	0
1939	15,967	15,967	0
1940	2,145	2,145	0
1941	6,371	6,371	0
SUB-TOTAL	2,180,386	2,136,250	44,136
Unknown	38,376	24,770	13,606
TOTAL	2,218,762	2,161,020	57,742

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1882	1,933	1887	1,423	1888	4,134	1889
	24	1894	8	1897	940	1908
	350	1941				
1883	3,231	1887	170	1897		
1884	957	1887	6	1897	798	1906
	480	1908	2,415	1910	484	1912
	174	1923				
1885	1,283	1887	1,491	1897	40	1909
	276	1912	240	1916	350	1930
	290	1935	115	1941		
1886	400	1886	6,614	1887	358	1894
	6	1897	787	1900		
1887	764	1889	108	1894	1,539	1895
	280	1910				
1888	2,803	1904	31	1933		
1889	102	1900	216	1926	620	1929
1890	40	1935	710	1936		
1895	506	1910				
1905	480	1936				
1906	1,304	1911				
1907	550	1911	249	1931	465	1939
1909	52	1941				
1913	632	1930				
1915	5	1922	71	1923		
1919	555	1922	623	1936		
1923	470	1925	394	1936		
1925	433	1926				
1928	32	1941				
1930	325	1936				

8-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1895	2,643	2,643	0
1896	768	768	0
1897	3,385	3,385	0
1899	658	658	0
1901	376	376	0
1903	1,832	1,832	0
1905	2,103	2,103	0
1907	1,281	1,181	100
1908	1,423	1,423	0
1909	696	696	0
1910	5,255	5,255	0
1911	840	840	0
1913	351	351	0
1914	3,485	3,485	0
1915	480	480	0
1916	3,207	3,207	0
1917	2,280	2,280	0
1918	537	537	0
1919	1,601	1,601	0
1920	5,682	5,682	0
1921	2,032	2,032	0
1922	10,973	10,973	0
1923	21,313	18,733	2,580
1924	12,992	12,992	0
1925	13,925	13,625	300
1926	8,379	8,379	0
1927	9,397	9,397	0
1928	13,312	13,312	0
1929	3,959	3,959	0
1930	6,280	6,280	0
1931	12,580	12,580	0
1932	2,359	2,359	0
1933	2,030	2,030	0
1934	2,740	2,740	0
1935	208	208	0
1936	2,048	2,048	0
1937	2,182	2,182	0
1938	5,434	5,434	0
1939	650	650	0
1940	687	687	0
1941	2,465	2,465	0
Total	174,828	171,848	2,980

Retirements by Years

Year Installed	Feet	Year
1907	100	1935
1923	2,580	1923
1924	300	1929

12-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1883	2,445	2,445	0
1884	9,200	9,200	0
1885	12,643	9,383	3,260
1886	14,146	12,168	1,978
1887	27,071	27,071	0
1888	27,567	27,557	10
1889	25,535	25,511	24
1890	14,890	14,435	455
1891	3,997	3,997	0
1892	15,388	15,388	0
1893	9,445	9,445	0
1894	4,084	4,084	0
1895	4,992	4,992	0
1896	2,363	2,363	0
1897	2,118	2,118	0
1899	270	270	0
1900	2,739	2,739	0
1901	4,185	4,185	0
1902	2,028	2,028	0
1903	8,208	8,208	0
1904	2,957	2,957	0
1905	9,494	9,494	0
1906	4,069	4,069	0
1907	15,816	15,641	175
1908	11,500	11,453	47
1909	12,975	12,975	0
1910	10,179	10,179	0
1911	1,590	1,590	0
1912	6,634	6,634	0
1913	4,103	4,103	0
1914	13,285	13,285	0
1915	5,475	5,475	0
1916	2,803	2,803	0
1917	5,687	5,687	0
1918	2,091	2,091	0
1919	3,466	3,466	0
1920	7,777	7,777	0
1921	1,806	1,806	0
1922	4,703	4,703	0
1923	7,274	7,274	0
1924	8,283	8,283	0
1925	10,171	10,171	0
1926	5,620	5,620	0
1927	6,007	6,007	0

12-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	4,427	4,427	0
1929	3,773	3,773	0
1930	8,138	8,138	0
1931	7,239	7,239	0
1932	5,932	5,932	0
1933	84	84	0
1935	210	210	0
1936	1,011	1,011	0
1937	500	500	0
1938	550	550	0
1939	4,136	4,136	0
1940	556	556	0
1941	2,000	2,000	0
TOTAL	395,635	389,686	5,949

Retirements by Years

Year Installed	Feet	Year	Year Installed	Feet	Year
1885	3,260	1887	1890	455	1939
1886	1,978	1887	1907	175	1935
1888	10	1897	1908	47	1911
1889	24	1895			

16-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1883	2,137	2,137	0
1884	7,679	7,679	0
1885	24,845	21,251	3,594
1886	5,410	5,410	0
1887	14,107	12,442	1,665
1888	6,081	6,081	0
1889	31,511	31,511	0
1890	15,890	15,890	0
1892	13,320	13,320	0
1894	2,991	2,991	0
1895	12	12	0
1897	324	324	0
1898	524	524	0
1899	312	312	0
1900	3,236	3,236	0
1902	794	794	0
1903	977	977	0
1904	8,351	8,351	0
1905	1,983	1,983	0
1906	2,711	2,050	661
1907	1,436	1,436	0
1908	9,501	7,561	1,940
1909	7,591	7,591	0
1910	7,594	7,594	0
1911	1,280	1,280	0
1912	2,223	2,223	0
1913	3,490	3,490	0
1914	3,392	3,392	0
1915	2,658	2,658	0
1916	3,736	3,736	0
1917	1,570	1,570	0
1918	1,608	1,608	0
1919	1,651	1,651	0
1920	6,088	6,088	0
1921	2,150	2,150	0
1922	4,316	4,316	0
1923	12,213	12,213	0
1924	16,378	16,184	194
1925	1,938	1,938	0
1926	10,792	10,792	0
1927	8,011	8,011	0
1928	1,077	1,077	0
1929	3,613	3,613	0
1930	1,000	1,000	0
1931	3,412	3,412	0
1932	940	940	0
1933	84	84	0
1936	80	80	0
1941	885	885	0
TOTAL	263,902	255,848	8,054

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1885	3,594	1887				
1887	50	1897	161	1918	211	1924
	1,243	1939				
1906	661	1931				
1908	1,940	1931				
1924	194	1939				

20-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1884	10,973	8,202	2,771
1885	4,642	4,642	0
1886	1,415	1,415	0
1887	4,795	4,795	0
1888	16,067	16,067	0
1889	4,585	4,585	0
1892	1,716	1,656	60
1895	12	12	0
1896	46	46	0
1897	27	27	0
1898	60	60	0
1905	6,555	6,555	0
1923	1,318	1,318	0
1924	1,195	1,195	0
1925	903	903	0
1926	1,756	1,756	0
1927	24	24	0
1929	1,865	1,865	0
1930	2,650	2,650	0
1932	1,912	1,912	0
1936	2,700	2,700	0
1939	924	924	0
1941	350	350	0
TOTAL	66,490	63,659	2,831

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1884	650	1923	2,121	1931
1892	60	1898		

24-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1883	25	25	0
1884	11,807	11,628	179
1887	50	50	0
1888	3,013	3,013	0
1889	2,235	2,235	0
1891	88	18	70
1895	18	18	0
1898	46	46	0
1912	3,844	3,844	0
1924	60	60	0
1925	2,724	2,724	0
1930	30	30	0
1931	3,900	3,900	0
1936	4,100	4,100	0
1941	52	52	0
TOTAL	31,992	31,743	249

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1884	25	1897	154	1898
1891	70	1898		

30-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1884	16,436	16,436	0
1895	9,234	9,234	0
1898	841	841	0
1912	10,391	10,391	0
1922	3,030	3,030	0
1923	15,018	15,018	0
1925	4,080	4,080	0
1926	2,600	2,600	0
1936	48	48	0
1941	0	0	0
TOTAL	61,678	61,678	0

36-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1884	18	18	0
1888	1,560	1,560	0
1896	7,353	6,668	685
1897	33	33	0
1898	154	154	0
1912	10,392	10,392	0
1923	1,143	1,143	0
1941	0	0	0
TOTAL	20,653	19,968	685

Retirements by Years

Year Installed	Feet	Year
1896	685	1923

42-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1923	11,237	11,237	0
1941	0	0	0
TOTAL	11,237	11,237	0

6-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1931	6,385	6,385	0
1932	8,487	8,487	0
1933	1,553	1,553	0
1934	1,581	1,581	0
1936	1,836	1,836	0
1937	4,794	4,794	0
1938	10,324	10,324	0
1939	2,639	2,639	0
1940	13,852	13,852	0
1941	11,187	11,187	0
Total	62,638	62,638	0

8-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1934	4,700	4,700	0
1941	0	0	0
Total	4,700	4,700	0

12-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1939	582	582	0
1940	114	114	0
1941	0	0	0
Total	696	696	0

4-in. Cement Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1882	888	0	888
1941	0	0	0
Subtotal	888	0	888
Unknown	8,926	0	8,926
Total	9,814	0	9,814

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1882	42	1896	300	1900	546	1903

6-in. Cement Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
Unknown	5,846	0	5,846
Total	5,846	0	5,846

12-in. Cement Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
Unknown	3,640	0	3,640
Total	3,640	0	3,640

16-in. Cement Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1887	6,000	0	6,000
1941	0	0	0
Subtotal	6,000	0	6,000
Unknown	23,359	0	23,359
Total	29,359	0	29,359

Retirements by Years

Year Installed	Feet	Year
1887	6,000	1920

24-in. Cement Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1885	7,024	0	7,024
1941	0	0	0
Subtotal	7,024	0	7,024
Unknown	7,000	0	7,000
Total	14,024	0	14,024

Retirements by Years

Year Installed	Feet	Year
1885	7,024	1920

3-IN. GALVANIZED-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1921	478	378	100
1926	1,083	1,083	0
1927	270	270	0
1941	0	0	0
TOTAL	1,831	1,731	100

Retirements by Years

Year Installed	Feet	Year
1921	100	1936

20-IN. STEEL MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1938	6,635	6,635	0
1939	1,774	1,774	0
1941	0	0	0
TOTAL	8,409	8,409	0

24-IN. STEEL MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1938	2,621	2,621	0
1941	0	0	0
TOTAL	2,621	2,621	0

30-IN. STEEL MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1938	8,014	8,014	0
1941	0	0	0
TOTAL	8,014	8,014	0

METERS

⅝-IN. DISC METERS

Year Installed	Number		
	Installed	In Service	Retired
1898	648	121	527
1899	449	65	384
1900	529	60	469
1901	558	56	502
1902	561	125	436
1903	408	139	269
1904	430	142	288
1905	689	172	517
1906	876	233	643
1907	671	260	411
1908	616	234	382
1909	773	292	481
1910	1,160	419	741
1911	750	289	461
1912	13,006	12,848	158
1914	10	6	4
1915	2,475	2,466	9
1916	1,985	1,978	7
1917	21	13	8
1918	1,500	1,476	24
1919	420	420	0
1920	1,481	1,474	7
1921	1,018	1,014	4
1922	2,877	2,874	3
1923	993	991	2
1924	993	989	4
1926	196	196	0
1928	223	223	0
1929	491	491	0
1930	1,498	1,496	2
1931	201	201	0
1932	100	100	0
1933	39	38	1
1934	202	202	0
1935	466	466	0
1936	667	667	0
1937	674	674	0
1938	397	397	0
1939	101	101	0
1940	359	359	0
1941	415	415	0
SUBTOTAL	41,926	35,182	6,744
Unknown	3,963	0	3,963
TOTAL	45,889	35,182	10,707

⅝-IN. DISC METERS (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1898	1	1916	2	1929	47	1930
	168	1931	126	1932	25	1933
	13	1934	25	1935	31	1936
	20	1937	18	1938	9	1939
	14	1940	28	1941		
1899	2	1913	5	1914	4	1915
	8	1916	6	1917	6	1918
	1	1919	4	1920	4	1921
	19	1922	12	1923	13	1924
	3	1925	1	1926	3	1927
	6	1928	6	1929	34	1930
	65	1931	78	1932	14	1933
	8	1934	12	1935	20	1936
	16	1937	6	1938	10	1939
	11	1940	7	1941		
1900	5	1913	11	1914	5	1915
	14	1916	8	1917	13	1918
	3	1919	1	1920	4	1921
	9	1922	27	1923	15	1924
	10	1925	12	1926	10	1927
	12	1928	18	1929	43	1930
	62	1931	82	1932	22	1933
	7	1934	7	1935	22	1936
	15	1937	13	1938	6	1939
	5	1940	8	1941		
1901	8	1913	9	1914	8	1915
	23	1916	7	1917	7	1918
	4	1919	3	1920	4	1921
	19	1922	31	1923	8	1924
	2	1925	2	1927	3	1928
	1	1929	40	1930	97	1931
	106	1932	13	1933	11	1934
	16	1935	29	1936	14	1937
	10	1938	10	1939	9	1940
	8	1941				
1902	1	1913	6	1914	5	1915
	7	1916	4	1917	4	1918
	3	1919	2	1920	3	1921
	10	1922	18	1923	4	1924
	1	1925	1	1926	2	1928
	1	1929	53	1930	42	1931
	66	1932	37	1933	18	1934
	19	1935	30	1936	25	1937
	20	1938	14	1939	20	1940
	20	1941				
1903	41	1930	24	1931	31	1932
	32	1933	21	1934	12	1935
	14	1936	33	1937	24	1938
	14	1939	17	1940	6	1941
1904	26	1930	31	1931	22	1932
	26	1933	21	1934	29	1935
	27	1936	42	1937	20	1938
1904	16	1939	13	1940	15	1941
1905	1	1923	2	1929	73	1930
	70	1931	51	1932	48	1933
	28	1934	40	1935	54	1936
	42	1937	26	1938	23	1939
	34	1940	25	1941		
1906	2	1929	60	1930	48	1931
	44	1932	57	1933	45	1934
	78	1935	76	1936	83	1937
	47	1938	26	1939	43	1940
	34	1941				
1907	1	1924	3	1929	18	1930
	12	1931	11	1932	22	1933
	19	1934	59	1935	71	1936
	68	1937	28	1938	28	1939
	34	1940	37	1941		
1908	1	1929	11	1930	7	1931
	16	1932	25	1933	22	1934
	43	1935	59	1936	73	1937
	34	1938	20	1939	40	1940
	31	1941				
1909	3	1929	15	1930	16	1931
	13	1932	18	1933	36	1934
	68	1935	68	1936	69	1937
	39	1938	33	1939	49	1940
	54	1941				
1910	1	1929	27	1930	37	1931
	35	1932	44	1933	40	1934
	78	1935	111	1936	108	1937
	79	1938	50	1939	68	1940
	63	1941				
1911	21	1930	9	1931	16	1932
	11	1933	15	1934	84	1935
	56	1936	77	1937	44	1938
	35	1939	40	1940	53	1941
1912	6	1913	8	1914	12	1915
	3	1916	5	1917	1	1918
	2	1919	2	1920	2	1922
	4	1923	4	1924	2	1925
	6	1926	6	1927	47	1928
	3	1929	6	1930	3	1931
	13	1932	5	1933	6	1934
	4	1935	4	1936	1	1937
	2	1939	1	1940		
1914	1	1927	1	1930	1	1932
	1	1935				
1915	2	1924	3	1928	3	1932
	1	1934	1	1941		
1916	2	1923	1	1931	2	1932
	1	1941				
1917	4	1917	1	1924	2	1929
	1	1940				

⅝-IN. DISC METERS (contd.)

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1918	2	1919	1	1920	2	1922	1921	1	1925	2	1929	1	1937
	2	1923	3	1924	5	1925	1922	2	1927	1	1928		
	4	1926	1	1928	1	1930	1923	1	1929	1	1933		
	1	1931	1	1934	1	1941	1924	1	1928	2	1929	1	1936
1920	2	1923	1	1924	1	1925	1930	1	1933	1	1935		
	2	1931	1	1934			1933	1	1935				

⅝–¾-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1921	2	2	0	1940	308	308	0
1922	1,997	1,996	1	1941	465	465	0
1924	2,490	2,488	2				
1925	3,387	3,380	7	SUBTOTAL	16,658	16,646	12
1926	799	799	0	Unknown	56	0	56
1927	1,189	1,188	1				
1928	998	997	1	TOTAL	16,714	16,646	68
1929	996	996	0				
1930	718	718	0				
1931	197	197	0				
1932	167	167	0				
1933	189	189	0				
1934	120	120	0				
1935	350	350	0				
1936	460	460	0				
1937	1,175	1,175	0				
1938	150	150	0				
1939	501	501	0				

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1922	1	1928				
1924	2	1930				
1925	1	1925	1	1930	1	1934
	1	1935	3	1936		
1927	1	1934				
1928	1	1930				

¾-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1903	19	4	15	1929	24	24	0
1904	13	2	11	1930	67	67	0
1905	28	2	26	1931	164	164	0
1906	33	7	26	1932	50	50	0
1907	35	3	32	1933	76	76	0
1908	63	4	59	1934	119	119	0
1909	94	20	74	1935	60	60	0
1910	52	5	47	1936	57	57	0
1911	80	21	59	1937	52	52	0
1912	38	2	36	1938	15	15	0
1913	399	397	2	1939	155	155	0
1915	300	300	0	1940	811	811	0
1916	298	297	1	1941	960	960	0
1918	301	301	0				
1921	1	1	0	SUBTOTAL	4,476	4,088	388
1923	100	100	0	Unknown	269	0	269
1925	1	1	0				
1927	1	1	0	TOTAL	4,745	4,088	657
1928	10	10	0				

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1903	1	1930	2	1931	1	1932		4	1940				
	2	1934	1	1935	3	1936	1909	10	1930	14	1931	3	1932
	3	1937	1	1938	1	1940		7	1933	6	1934	5	1935
1904	1	1930	1	1931	3	1932		6	1936	10	1937	3	1938
	1	1933	2	1935	2	1937		4	1939	4	1940	2	1941
	1	1940					1910	2	1930	7	1931	8	1932
1905	1	1925	1	1927	1	1928		6	1933	4	1934	6	1935
	1	1929	1	1930	4	1931		3	1936	3	1937	1	1938
	6	1932	4	1933	4	1934		1	1939	4	1940	2	1941
	1	1936	1	1937	1	1939	1911	3	1930	10	1931	6	1932
1906	1	1923	1	1930	4	1931		4	1933	7	1934	2	1935
	9	1932	2	1933	1	1934		8	1936	8	1937	5	1938
	1	1935	3	1936	3	1937		5	1940	1	1941		
	1	1940					1912	1	1913	1	1914	2	1915
1907	5	1931	2	1932	4	1933		1	1916	3	1918	1	1919
	6	1934	2	1935	2	1936		2	1920	2	1925	2	1926
	2	1937	3	1938	3	1939		5	1928	1	1929	1	1930
	1	1940	2	1941				12	1932	2	1936		
1908	4	1930	8	1931	11	1932	1913	1	1935	1	1939		
	8	1933	2	1934	6	1935	1916	1	1938				
	4	1936	11	1937	1	1939							

1-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1903	23	5	18	1927	100	100	0
1904	23	2	21	1928	20	20	0
1905	13	5	8	1929	74	74	0
1906	22	3	19	1930	150	150	0
1907	26	2	24	1931	98	98	0
1908	45	6	39	1932	49	49	0
1909	37	14	23	1934	10	10	0
1910	57	9	48	1935	45	45	0
1911	34	11	23	1936	145	145	0
1912	346	313	33	1937	115	115	0
1913	105	105	0	1938	200	200	0
1915	74	73	1	1939	205	205	0
1918	163	160	3	1940	220	220	0
1920	6	6	0	1941	165	165	0
1922	110	110	0				
1923	104	104	0	SUBTOTAL	3,144	2,884	260
1924	212	212	0	Unknown	293	0	293
1925	50	50	0				
1926	98	98	0	TOTAL	3,437	2,884	553

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1903	3	1930	2	1931	6	1932	1904	2	1930	2	1931	1	1932
	2	1933	1	1934	2	1937		2	1933	1	1934	2	1935
	2	1938						6	1936	1	1937	1	1938

1-IN. DISC METERS (contd.)

Retirements by Years (contd.)

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
	1	1939	1	1940	1	1941	1909	1	1939	2	1940	3	1941
1905	1	1930	2	1931	2	1932	1910	3	1930	9	1931	6	1932
	1	1933	1	1937	1	1939		4	1933	3	1934	3	1935
1906	2	1930	6	1931	1	1932		7	1936	7	1937	2	1938
	4	1933	1	1934	2	1935		1	1939	3	1940		
	1	1936	1	1940	1	1941	1911	1	1923	1	1930	5	1931
1907	3	1930	2	1931	3	1932		1	1932	2	1933	2	1934
	3	1933	1	1934	6	1935		1	1935	7	1936	1	1938
	1	1936	3	1937	1	1939		2	1939				
	1	1940					1912	1	1913	5	1914	1	1915
1908	3	1930	3	1931	6	1932		1	1919	1	1921	1	1922
	6	1933	1	1934	3	1935		4	1924	1	1925	1	1926
	2	1936	6	1937	2	1938		2	1927	2	1929	11	1932
	4	1939	2	1940	1	1941		1	1935	1	1939		
1909	6	1930	4	1931	2	1933	1915	1	1932				
	1	1934	1	1936	3	1938	1918	3	1933				

1¼-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1912	143	143	0	Unknown	5	0	5
1915	30	30	0				
1917	69	68	1	TOTAL	261	255	6
1920	6	6	0				
1923	8	8	0		*Retirements by Years*		
1941	0	0	0	Year Installed	Number	Year	
SUBTOTAL	256	255	1	1917	1	1929	

1½-IN. DISC METERS

Year Installed	Number Installed	Number In Service	Number Retired	Year Installed	Number Installed	Number In Service	Number Retired
1903	9	0	9	1927	49	49	0
1904	10	0	10	1929	10	10	0
1905	3	0	3	1930	75	75	0
1906	5	0	5	1931	54	54	0
1907	14	0	14	1932	30	30	0
1908	32	0	32	1933	5	5	0
1909	17	1	16	1934	10	10	0
1910	25	0	25	1935	27	27	0
1911	24	0	24	1937	40	40	0
1912	126	87	39	1938	60	60	0
1915	15	15	0	1939	20	20	0
1917	60	59	1	1941	0	0	0
1921	18	18	0				
1922	161	160	1	SUBTOTAL	1,081	902	179
1923	73	73	0	Unknown	140	0	140
1924	61	61	0				
1926	48	48	0	TOTAL	1,221	902	319

1½-in. Disc Meters (contd.)

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1903	1	1932	2	1933	5	1935	1909	2	1938				
	1	1939					1910	3	1931	5	1932	2	1934
1904	1	1930	1	1931	2	1932		4	1935	1	1936	6	1938
	1	1933	1	1934	2	1935		2	1939	2	1940		
	2	1938					1911	4	1931	3	1933	1	1935
1905	1	1933	2	1935				1	1936	1	1937	13	1938
1906	1	1930	2	1931	2	1935		1	1939				
1907	1	1930	2	1931	1	1934	1912	2	1913	2	1914	2	1917
	6	1935	1	1937	2	1938		1	1919	1	1920	2	1922
	1	1939						1	1923	1	1924	2	1925
1908	4	1930	3	1931	1	1932		6	1929	4	1931	13	1932
	1	1933	5	1935	2	1936		1	1934	1	1940		
	9	1937	7	1938			1917	1	1932				
1909	2	1930	4	1931	2	1932	1922	1	1935				
	1	1934	3	1935	2	1937							

2-in. Disc Meters

Year Installed	Number			Year Installed	Number		
	Installed	In Service	Retired		Installed	In Service	Retired
1903	1	0	1	1919	19	18	1
1904	2	0	2	1922	103	102	1
1905	5	0	5	1924	25	25	0
1906	3	0	3	1927	24	24	0
1907	7	0	7	1928	25	25	0
1908	12	0	12	1930	28	28	0
1909	11	1	10	1936	10	10	0
1910	10	0	10	1941	0	0	0
1911	5	0	5		—	—	—
1912	75	63	12	Subtotal	500	425	75
1913	110	107	3	Unknown	107	0	107
1915	19	16	3		—	—	—
1917	6	6	0	Total	607	425	182

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1903	1	1932					1910	1	1930	1	1932	3	1933
1904	1	1933	1	1935				1	1935	1	1938	3	1940
1905	1	1929	1	1933	1	1935	1911	1	1919	1	1931	1	1932
	1	1937	1	1939				1	1933	1	1936		
1906	1	1934	1	1935	1	1940	1912	1	1914	1	1916	1	1919
1907	1	1930	3	1931	1	1934		1	1923	1	1924	4	1929
	1	1935	1	1940				2	1932	1	1935		
1908	1	1933	3	1935	7	1938	1913	1	1932	1	1934	1	1936
	1	1939					1915	1	1930	1	1931	1	1940
1909	1	1930	1	1933	2	1934	1919	1	1932				
	2	1935	1	1936	1	1937	1922	1	1936				
	1	1939	1	1940									

3-IN. DISC METERS

Year Installed	Number Installed	In Service	Retired
1913	1	1	0
1914	1	1	0
1916	2	1	1
1917	2	0	2
1918	4	0	4
1922	1	1	0
1941	0	0	0
TOTAL	11	4	7

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1916	1	1933				
1917	1	1927	1	1930		
1918	1	1929	1	1931	1	1933
	1	1934				

4-IN. DISC METERS

Year Installed	Number Installed	In Service	Retired
1912	2	0	2
1916	1	0	1
1917	1	0	1
1941	0	0	0
TOTAL	4	0	4

Retirements by Years

Year Installed	Number	Year	Number	Year
1912	1	1932	1	1940
1916	1	1930		
1917	1	1933		

2-IN. COMPOUND METERS

Year Installed	Number Installed	In Service	Retired
1931	2	2	0
1932	2	2	0
1933	6	6	0
1934	1	1	0
1935	6	6	0
1936	10	10	0
1937	5	5	0
1939	4	4	0
1940	6	6	0
1941	8	8	0
TOTAL	50	50	0

3-IN. COMPOUND METERS

Year Installed	Number Installed	In Service	Retired
1916	2	0	2
1920	6	0	6
1921	6	0	6
1922	6	0	6
1923	5	0	5
1924	6	0	6
1925	11	2	9
1926	6	5	1
1927	1	1	0
1928	13	8	5
1929	9	3	6
1930	16	15	1
1931	9	9	0
1932	15	15	0
1933	7	7	0
1934	7	7	0
1935	7	7	0
1936	8	8	0
1937	6	6	0
1938	7	7	0
1939	10	10	0
1940	9	9	0
1941	1	1	0
SUBTOTAL	173	120	53
Unknown	1	0	1
TOTAL	174	120	54

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1916	1	1932	1	1933		
1920	2	1931	1	1935	1	1937
	1	1939	1	1940		
1921	3	1935	2	1936	1	1940
1922	1	1932	1	1934	1	1935
	1	1936	1	1937	1	1938
1923	2	1935	1	1938	1	1939
	1	1940				
1924	1	1933	1	1935	1	1936
	1	1937	1	1938	1	1940
1926	1	1938				
1928	1	1931	1	1936	1	1938
	2	1940				
1929	1	1931	1	1932	4	1933
1930	1	1940				

4-in. Compound Meters

Year Installed	Number Installed	Number In Service	Number Retired
1915	3	0	3
1918	1	0	1
1919	4	0	4
1920	12	0	12
1922	4	3	1
1923	5	0	5
1925	6	0	6
1926	9	3	6
1927	6	2	4
1928	6	5	1
1929	1	1	0
1930	5	5	0
1931	6	6	0
1932	6	6	0
1933	3	3	0
1934	6	6	0
1935	6	6	0
1936	6	6	0
1937	6	6	0
1938	4	4	0
1939	7	7	0
1940	5	5	0
1941	1	1	0
Subtotal	118	75	43
Unknown	1	0	1
Total	119	75	44

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year
1915	2	1934	1	1940		
1918	1	1931				
1919	2	1931	1	1934	1	1939
1920	2	1933	2	1934	1	1935
	2	1936	2	1937	1	1939
	2	1940				
1922	1	1931				
1923	1	1931	1	1934	1	1935
	2	1937				
1925	3	1936	1	1938	2	1940
1926	1	1934	1	1936	1	1937
	2	1939	1	1940		
1927	2	1939	2	1940		
1928	1	1939				

6-in. Compound Meters

Year Installed	Number Installed	Number In Service	Number Retired
1912	2	0	2
1914	3	1	2
1917	5	0	5
1919	2	1	1
1920	1	0	1
1922	1	0	1
1923	1	0	1
1924	4	3	1
1925	2	0	2
1926	2	0	2
1927	1	1	0
1929	1	1	0
1930	3	3	0
1931	4	4	0
1932	2	2	0
1933	3	3	0
1936	2	2	0
1937	3	3	0
1938	1	1	0
1940	1	1	0
1941	0	0	0
Total	44	26	18

Retirements by Years

Year Installed	Number	Year	Number	Year
1912	1	1930	1	1931
1914	1	1931	1	1934
1917	1	1930	4	1931
1919	1	1931		
1922	1	1932		
1923	1	1938		
1924	1	1938		
1925	1	1935	1	1939
1926	1	1932	1	1937

8-in. Compound Meters

Year Installed	Number Installed	Number In Service	Number Retired
1935	1	1	0
1937	1	1	0
1941	0	0	0
Total	2	2	0

3-IN. TURBINE METERS

Year Installed	Number Installed	Number In Service	Number Retired
1914	1	1	0
1918	7	0	7
1923	1	1	0
1926	1	1	0
1927	1	1	0
1928	3	3	0
1929	1	1	0
1930	1	1	0
1935	1	1	0
1936	1	1	0
1941	1	1	0
TOTAL	19	12	7

Retirements by Years

Year Installed	Number	Year	Number	Year
1918	4	1930	3	1932

4-IN. TURBINE METERS

Year Installed	Number Installed	Number In Service	Number Retired
1916	1	1	0
1917	4	2	2
1920	2	1	1
1923	1	1	0
1929	1	1	0
1932	1	1	0
1941	0	0	0
TOTAL	10	7	3

4-IN. TURBINE METERS (contd.)

Retirements by Years

Year Installed	Number	Year
1917	2	1935
1920	1	1930

6-IN. TURBINE METERS

Year Installed	Number Installed	Number In Service	Number Retired
1912	1	0	1
1917	2	2	0
1923	1	1	0
1924	1	1	0
1925	2	2	0
1926	4	3	1
1928	1	1	0
1929	1	1	0
1941	0	0	0
TOTAL	13	11	2

Retirements by Years

Year Installed	Number	Year
1912	1	1934
1926	1	1940

8-IN. TURBINE METERS

Year Installed	Number Installed	Number In Service	Number Retired
1917	1	1	0
1941	0	0	0
TOTAL	1	1	0

Scranton, Pennsylvania—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Scranton-Spring Brook Water Service Company, said to be the largest contiguously integrated, privately owned operating water company in the United States, serves 55 municipalities, including the cities of Scranton and Wilkes-Barre, comprising a large part of the northern anthracite coal region of eastern Pennsylvania. The territory included in the service area extends for 70 mi. along both sides of the Susquehanna and Lackawanna rivers from Glen Lyon, located south of Wilkes-Barre, to Forest City, north of Scranton.

The company serves water to 128,917 customers, comprising a population of 650,000 people and, in addition, serves manufactured gas to 29,111 customers in thirteen municipalities. The water property includes 71 storage reservoirs located on mountain streams, which have a combined storage of approximately 20 bil.gal. An average of 84 mil.gal. of water is supplied daily through a transmission and distribution system consisting of 1,284 mi. of all sizes of mains up to 48 in. in diameter.

Development of the Existing System

The Scranton-Spring Brook Water Service Company was formed in 1928 as a subsidiary of the Federal Water Service Company, now the Federal Water and Gas Corporation, by the merger of the Scranton Gas and Water Company, which served Scranton and communities to the north, and the Spring Brook Water Supply Company, which served communities, including Wilkes-Barre, south of Scranton.

Each of these companies, in turn, was the result of the merger, consolidation and absorption of 30 to 40 smaller local water companies during a period of nearly 100 years of operation.

For operating convenience the property is divided into two main operating divisions, along the lines of the two predecessor companies, and each division takes its name from the predecessor company.

The Spring Brook Division, serving a 90-sq.mi. area including and surrounding Wilkes-Barre, supplies 355,000 persons who require an average of 50 mgd. This service is supplied from 30 reservoirs storing 11.3 bil.gal. through a system of mains 3 to 48 in. in size, totaling about 754 mi.

The Scranton Division, serving a 75-sq.mi. area including Scranton and sixteen communities north of it, supplies 42,596 customers, or 252,220 people, who require an average of 34 mgd. Service to this division is also from impounding reservoirs, 41 in number, having a total capacity in excess of 8 bil.gal., through 530 mi. of mains, 4 to 48 in. in diameter.

The Scranton Division has been further subdivided for operating purposes into two districts, the Scranton

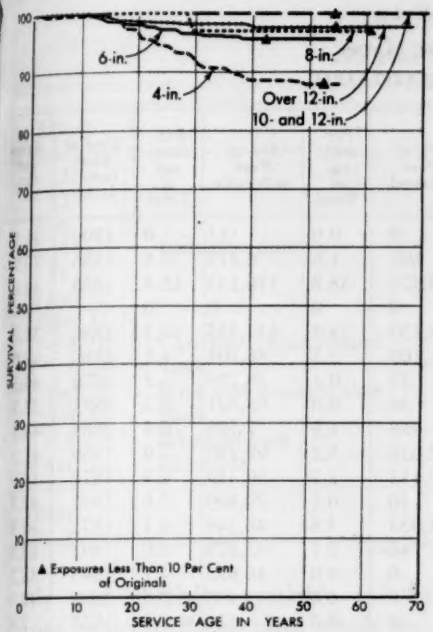

FIG. 1. Mortality Survival Curve—4–48-in. Cast-Iron Unlined Mains—Scranton, Pennsylvania

BASE: Feet SURVIVAL: 1870–1940

SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	195,704	19,571
6	448,494	14,159
8	47,864	1,160
10 and 12	135,445	55
Over 12	317,440	6,714

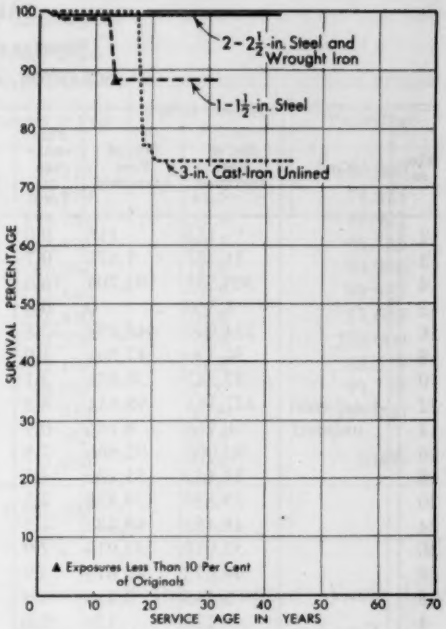
2–2½-in. Steel and Wrought Iron
1–1½-in. Steel
3-in. Cast-Iron Unlined
▲ Exposures Less Than 10 Per Cent of Originals
SURVIVAL PERCENTAGE
SERVICE AGE IN YEARS

FIG. 2. Mortality Survival Curve—1–3-in. Mains—Scranton, Pennsylvania

BASE: Feet SURVIVAL: 1896–1940

SIZE	KIND	EXPOSURES	RETIREMENTS
in.		*ft.*	*ft.*
1–1½	Steel	7,709	252
2–2½	Steel and Wrought-Iron	14,087	35
3	Cast-Iron Unlined	7,679	800

Water District, comprising the city of Scranton and Borough of Dunmore, and the Consolidated District, comprising all municipalities north of Scranton. The Scranton Division contains 42,744 services, with 84 per cent of the customers being supplied through 36,201 meters. There are 8,045 valves and 1,858 fire hydrants in service.

The Scranton Water District, with which this report is primarily concerned, serves 26,271 metered customers comprising a population of 161,386, requiring 21.3 mgd. of water, supplied through 300.3 mi. of 4- to 48-in. mains. The district contains 27,008 services, 4,936 valves and 1,152 fire hydrants.

Basis of Study

This report is concerned with an analysis of pipe installations and retirements in the Scranton Water District only. The records of such installations and retirements are substantially complete from 1885 to the date of the

TABLE 1

SUMMARY OF MAINS
SCRANTON, PENNSYLVANIA

Size, in.	Kind	No. of Feet Installed	No. of Feet Identified	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, yr.
2	Cast-iron unlined	115	115	0.0	0	0.0	115	0	1909	31.5
3		31,277	7,679	0.7	800	1.6	6,879	0.6	1986	20.9
4		309,581	195,704	16.6	19,571	38.8	176,133	15.5	1885	40.6
5		1,360	0	0.0	0	0	0	0	—	—
6		734,997	448,494	37.8	14,159	28.1	434,335	38.3	1886	31.0
8		56,320	47,864	4.0	1,160	2.3	46,704	4.1	1880	45.0
10		37,347	36,834	3.1	35	0.1	36,799	3.2	1870	45.5
12		137,161	98,611	8.3	20	0.0	98,591	8.7	1891	32.7
14		8,766	8,766	0.7	968	1.9	7,798	0.7	1884	44.2
16		93,000	92,866	7.8	2,620	5.2	90,246	7.9	1880	41.3
18		51,432	51,432	4.3	1,113	2.2	50,319	4.4	1872	44.0
20		29,859	29,859	2.5	40	0.1	29,819	2.6	1891	37.7
24		48,482	48,482	4.1	1,933	3.8	46,549	4.1	1872	46.9
30		33,919	33,919	2.9	40	0.1	33,879	3.0	1893	42.9
36		46,673	46,673	3.9	0	0.0	46,673	4.1	1893	38.2
48		5,443	5,443	0.5	0	0.0	5,443	0.5	1897	32.9
4	Cast-iron cement-lined	126	126	0.0	0	0.0	126	0.0	1935	2.6
6		3,034	3,034	0.3	0	0.0	3,034	0.3	1925	9.2
8		1,044	1,044	0.1	0	0.0	1,044	0.1	1934	3.9
16		98	98	0.0	0	0.0	98	0.0	1933	7.0
1	Steel	2,538	2,538	0.2	222	0.4	2,316	0.2	1927	5.3
1¼		926	926	0.1	30	0.1	896	0.1	1920	10.5
1½		3,305	3,305	0.3	0	0.0	3,305	0.3	1909	6.4
2		5,556	5,556	0.5	35	0.1	5,521	0.5	1914	16.2
2½		22	22	0.0	0	0.0	22	0.0	1928	12.5
3		8	8	0.0	0	0.0	8	0.0	1928	12.5
6	Galvanized steel	426	426	0.0	0	0.0	426	0.0	1895	4.7
8		255	255	0.0	0	0.0	255	0.0	1893	46.7
10		125	125	0.0	0	0.0	125	0.0	1928	12.5
1½	Steel cement-lined	360	360	0.0	0	0.0	360	0.0	1936	4.5
2		6,026	6,026	0.5	0	0.0	6,026	0.5	1928	8.1
1	Steel lead-lined	167	167	0.0	0	0.0	167	0.0	1939	1.5
1¼		160	160	0.0	0	0.0	160	0.0	1939	1.5
1½		253	253	0.0	0	0.0	253	0.0	1937	3.5
2		483	483	0.0	0	0.0	483	0.0	1931	8.2
2		2,000	2,000	0.2	0	0.0	2,000	0.2	1898	40.9
8	Wrought-iron	120	120	0.0	0	0.0	120	0.0	1912	28.5
10		125	125	0.0	125	0.2	0	0.0	1916	—
16		110	110	0.0	110	0.2	0	0.0	1897	—
18	Kalamein	3,580	3,580	0.3	3,580	7.1	0	0.0	1872	—
20		3,905	3,905	0.3	3,905	7.7	0	0.0	1872	—
TOTAL		1,660,484	1,187,493	100.0	50,466	100.0	1,137,027	100.0		36.2
Percentage of Total			100.00		4.25		95.75			
Average Size, in.			10.86		8.82		10.95			

TABLE 1 (contd.)

Mortality Survival Ratios

Size, *in.*	Kind	Number of Feet	Period Covered, *yr.*	Percentage
2	Cast-iron unlined	115	31.5	100.000
3		7,679	44.5	74.525
4		195,704	55.5	87.927
6		448,494	54.5	95.752
8		47,864	60.5	96.976
10 and 12		135,445	70.5	99.957
Over 12		317,440	68.5	97.628
4–16	Cast-iron cement-lined	4,302	15.5	100.000
1–1½	Steel	7,709	31.5	88.521
2 and 2½	Steel and wrought-iron	14,087	42.5	99.737
3–10	Steel	814	47.5	100.000
8–16	Wrought-iron	355	43.5	—
18 and 20	Kalamein	7,485	40.5	0.000
TOTAL		1,187,493		

study and partially available for an earlier period. Some pipe which was purchased in assembling the system has been included in the study as of the purchase date.

Mortality Survival Study

Mortality studies were made of mains only. Table 1 gives a summary of the pipe installed and that identified as well as the retirements of identified pipe and other pertinent data. Figures 1 and 2 show the mortality survival curves covering the record of the pipe grouped as shown.

Also given is a summary of Class B facilities of the Scranton Water District.

Causes of Retirement

The record does not give the causes dictating the retirement of pipe. A few retirements have resulted from a cause which could be present in but few cities in the United States, namely, mine subsidence.

Acknowledgment

The collection and compilation of the data in the Scranton plant were under the general supervision of Marc Baum of the Scranton-Spring Brook Water Service Company.

SUMMARY OF CLASS B FACILITIES
SCRANTON, PENNSYLVANIA

Impounding Reservoirs

Lake Henry—Formed by damming Lake Henry Creek. Earth embankment dam with masonry core wall, 6 ft. wide on top, 10 ft. maximum height, 1,140 ft. long; capacity 205 mil.gal.; drainage area 0.9 sq.mi. Constructed in 1895–96 and still in service.

Lake Scranton—Formed by draining Stafford Meadow Brook. Earth embankment dam with masonry core wall, 12 ft. wide on top, 87 ft. maximum height, 590 ft. long; capacity 2,518 mil.gal.; drainage area 6 sq.mi. Constructed in 1893 and still in service.

Gouldsboro Pump Reservoir—Formed by damming Lehigh River. Earth embankment

dam with masonry and steel pile core wall, 12 ft. wide on top, 28 ft. maximum height, 330 ft. long; capacity 80 mil.gal.; drainage area 15.2 sq.mi. Constructed in 1910 and still in service. Present dam replaced stone filled crib dam built in 1895–96.

Dunmore No. 1—Formed by damming Little Roaring Brook. Earth embankment dam with masonry core wall, 8 ft. wide on top, 58 ft. maximum height, 490 ft. long; capacity 75 mil.gal.; drainage area 5.16 sq.mi. Constructed in 1891–92, raised 3.5 ft. in 1900 and 2.5 ft. in 1903; still in service. Present dam replaced earth dam with plank core wall built prior to 1870.

Summit Lake—Formed by damming Summit Lake Creek. Earth embankment with masonry core wall, 10 ft. wide on top, 25 ft. maximum height, 240 ft. long; capacity 259 mil.gal.; drainage area 0.96 sq.mi. Constructed in 1875–76 and still in service.

Maple Lake—Formed by damming Summit Lake Creek. Earth embankment with plastered core wall, 4 ft. wide on top, 22 ft. maximum height, 206 ft. long; capacity 3.7 mil.gal.; drainage area 2.11 sq.mi. Constructed prior to 1890 and still in service.

Dunmore No. 3—Formed by damming Little Roaring Brook. Earth embankment with plank core wall, 10 ft. wide on top, 10 ft. maximum height, 350 ft. long; capacity 18 mil.gal., drainage area 0.13 sq.mi. Constructed in 1851 and still in service.

Dunmore No. 4—Similar to No. 3 except 9 ft. wide on top, 15 ft. maximum height, 600 ft. long; capacity 10 mil.gal.; drainage area 0.25 sq.mi. Constructed in 1851 and still in service.

No. 7—Formed by damming Roaring Brook. Gravity-type masonry dam, 4 ft. wide on top, 45 ft. maximum height, 317 ft. long; capacity 122.5 mil.gal.; drainage area 50 sq.mi. Constructed in 1872; 4 ft. concrete flood wall added in 1902; still in service.

No. 5—Formed by damming Stafford Meadow Brook. Earth embankment with masonry core wall, 3 ft. wide on top, 40 ft. maximum height, 450 ft. long; capacity 32 mil.gal.; drainage area 11.5 sq.mi. Constructed in 1887–90; raised, lengthened and spillway capacity increased; still in service.

Curtis—Formed by damming Oak Run. Earth embankment with masonry core wall, 10 ft. wide on top, 40 ft. maximum height, 377 ft. long; capacity 418 mil.gal.; drainage area 2.4 sq.mi. Constructed in 1887; raised and strengthened; still in service.

Elmhurst—Formed by damming Roaring Brook. Earth embankment with masonry core wall, 8 ft. wide on top, 50 ft. maximum height, 383.5 ft. long; capacity 1,221 mil.gal.; drainage area 37.25 sq.mi. Constructed in 1887–90; raised 3 ft. in 1899, lowered 3 ft. in 1916 and strengthened; still in service.

La Rue—Formed by damming Summit Lake Creek. Gravity masonry dam, 4.5 ft. wide on top, 40 ft. maximum height, 124 ft. long; capacity 0.7 mil.gal.; drainage area 2.35 sq.mi. Constructed in 1907 and still in service.

Griffin—Formed by damming Griffin Creek. Earth embankment with masonry core wall, 22 ft. wide on top, 43 ft. maximum height, 429 ft. long; capacity 649 mil.gal.; drainage area 3.21 sq.mi. Constructed in 1887–88 and still in service.

Providence H.S.—Formed by damming Leggetts Creek. Masonry dam and rock fill, 21 ft. wide on top, 17 ft. maximum height, 210 ft. long; capacity 3.7 mil.gal.; drainage area 7.96 sq.mi. Original crib dam constructed prior to 1885; reconstructed in 1901; still in service.

Marshwood—Formed by damming Little Roaring Brook. Earth embankment with masonry core wall, 12 ft. on top, 15 ft. maximum height, 326 ft. long; capacity 48 mil. gal.; drainage area 1.8 sq.mi. Constructed in 1927 and still in service.

Nay Aug—Formed by damming Roaring Brook. Gravity type masonry dam, 5 ft. wide on top, 10 ft. maximum height, 50 ft. long; capacity not determined. Constructed in 1867 and retired in 1872–73 because of pollution of stream by mine drainage, resulting in construction of No. 7 upstream.

Distribution Reservoirs

Madison and Olive—Earth embankment, masonry core wall, concrete lining, uncovered, 100 ft. by 100 ft. in plan, 12 ft. deep; capacity 0.9 mil.gal. Constructed in 1857 and retired in 1893 because of elevation.

No. 6 High-Service—Earth embankment, masonry walls on inside, 165 ft. by 165 ft. in top plan, 18 ft. deep uncovered; capacity 2.63 mil.gal. Constructed in 1891; failed and retired in 1909 due to mine subsidence.

Providence Low-Service—Earth embankment with masonry core wall, uncovered, 73 ft. by 400 ft. in plan, 6 ft. deep; capacity 1.29 mil.gal. Constructed in 1882 and retired in 1911 upon completion of Chinchilla Filter Plant.

Providence Fountain—Earth embankment with masonry core wall uncovered, triangular in plan 20 ft. by 144 ft. by 440 ft., 4 ft. deep; capacity 0.916 mil.gal. Constructed in 1868 and retired in 1911 upon completion of Chinchilla Filter Plant.

Dunmore No. 2—Earth embankment with masonry core wall, uncovered, 130 ft. by 225 ft. in plan, 5.2 ft. deep; capacity 1.15 mil.gal. Constructed in 1900 and abandoned in 1902 due to leakage resulting from mine subsidence.

Tunnels and Aqueducts

Lake Scranton No. 1—Rock tunnel, 7 ft. by 7 ft., 2,871 ft. long, containing 30-in. cast-iron pipeline. Constructed in 1898–99 and still in service.

Lake Scranton No. 2—Rock tunnel, 7 ft. by 9 ft., 4,075 ft. long, containing 48-in. cast-iron pipeline. Constructed in 1907–1908 and still in service.

Wells

Nay Aug No. 1—10-in. drilled well, cased wrought iron 466 ft., uncased 254 ft.; pumped by air lift; capacity 200 gpm. Installed in 1910–11 and still in service.

Nay Aug No. 2—Similar to No. 1 except cased 486 ft., uncased 188 ft. Installed in 1910–11 and still in service.

Nay Aug No. 3—Similar to No. 1 except 452 ft. cased, 28 ft. uncased. Installed in 1910–11 and still in service.

Nay Aug No. 4—Similar to No. 1 except uncased 286 ft. Installed in 1910–11 and still in service.

Nay Aug No. 5—Similar to No. 1 except size is 12-in. and uncased 177 ft. Installed in 1910–11 and still in service.

Nay Aug No. 6—Similar to No. 5 except cased 616 ft., uncased 404 ft. Installed in 1910–11 and still in service.

Nay Aug No. 7—Similar to No. 6. Installed in 1910–11 and still in service.

NOTE: These wells are used as auxiliary supplies.

Purification Plant

Chinchilla Filter Plant—Gravity, concrete, rapid sand filter plant; 6-mgd. nominal capacity. Constructed in 1909–10 and still in service. Used during periods of emergency only.

Pumping Equipment

No. 6 Pumping Station—Horizontal compound steam pump, rated 2-mgd. capacity at 150-ft. head; 75 hp. Delivered water from No. 7 pipeline to No. 6 High-Service Reservoir. Installed in 1891–92 and retired in 1908 due to completion of parallel line from Williamsburg Bridge supply, which eliminated its need.

Lehigh Pumping Station—Horizontal compound steam pump, rated 10-mgd. capacity at 21-ft. head; two 150-hp. boilers; operated during extreme dry periods to deliver water from Lehigh River to Roaring Brook headwaters. Installed in 1895 and still in service.

Nay Aug Pumping Station—One single cylinder, steam-driven air compressor, 381-cfm. capacity; and one two-cylinder steam-driven air compressor, 1,650-cfm. capacity, with six 60-hp. steam boilers. Used for pumping by air Nay Aug wells. Installed in 1910–11; compressors still in service; one boiler retired in 1914 and five in 1918. Salvage value $4,250; original cost $6,000.

Two two-cylinder, pelton, water-wheel-driven air compressors, 1,650- and 1,965-cfm. capacity. Installed in 1910–11 and still in service.

Carbon Street Pumping Station—Steam driven displacement pump, details not known. Used for delivering water from Lackawanna River to distribution system. Installed in 1857 and retired 1867 due to mine drainage pollution of Lackawanna River.

Elevated Standpipes

Chinchilla Standpipe—Covered steel standpipe, 26.5-ft. diameter, 36 ft. high; capacity 150,000 gal. Erected in 1909 and still in service during operation of filter plant.

Summary of Installations and Retirements
Scranton, Pennsylvania

MAINS

2-in. Cast-Iron Unlined Mains*

Year Installed	Feet Installed	Feet In Service	Feet Retired
1909	115	115	0
1940	0	0	0
Total	115	115	0

* 13,244 ft. of 2-in. cast-iron pipe in Dunmore system, installed prior to 1900, was retired from 1901 to 1940.

3-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1896	395	295	100
1897	700	0	700
1901	937	937	0
1908	19	19	0
1909	30	30	0
1910	117	117	0
1912	30	30	0
1913	128	128	0
1915	40	40	0

3-in. Cast-Iron Unlined Mains (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1916	160	160	0
1917	45	45	0
1920	485	485	0
1921	65	65	0
1923	400	400	0
1924	335	335	0
1925	1,118	1,118	0
1926	1,710	1,710	0
1927	965	965	0
1940	0	0	0
Subtotal	7,679	6,879	800
Unknown	23,598	4,555	19,043
Total	31,277	11,434	19,843

Retirements by Years

Year Installed	Feet	Year
1896	100	1916
1897	700	1915

4-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1885	6,089	3,989	2,100
1886	2,620	2,620	0
1887	10,552	10,420	132
1888	1,150	930	220
1889	8,710	8,148	562
1890	3,901	3,411	490
1891	7,559	5,597	1,962
1892	14,399	11,935	2,464
1893	10,685	9,704	981
1894	4,691	4,621	70
1895	10,936	9,583	1,353
1896	16,247	14,262	1,985
1897	11,411	10,517	894
1898	10,580	8,662	1,918
1899	12,636	11,571	1,065
1900	3,980	3,750	230
1901	5,930	5,900	30
1902	10,425	8,200	2,225
1903	8,450	8,370	80
1904	1,421	1,021	400
1905	1,403	1,403	0
1906	620	470	150
1907	972	972	0
1908	676	676	0
1909	334	334	0
1910	677	677	0
1911	205	205	0
1912	981	981	0
1913	1,047	1,047	0
1914	368	368	0
1915	265	265	0
1916	545	545	0
1917	470	210	260
1918	105	105	0
1919	2,945	2,945	0
1920	530	530	0
1921	610	610	0
1922	720	720	0

4-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1923	1,075	1,075	0
1924	3,030	3,030	0
1925	2,913	2,913	0
1926	2,165	2,165	0
1927	5,985	5,985	0
1928	1,881	1,881	0
1929	1,834	1,834	0
1930	634	634	0
1931	135	135	0
1934	144	144	0
1939	3	3	0
1940	60	60	0
SUBTOTAL	195,704	176,133	19,571
Unknown	113,877	83,175	30,702
TOTAL	309,581	259,308	50,273

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1885	2,100	1915				
1887	132	1934				
1888	220	1926				
1889	162	1900	400	1912		
1890	490	1924				
1891	930	1911	828	1927	204	1940
1892	840	1915	150	1919	235	1927
	685	1930	554	1931		
1893	981	1924				
1894	70	1920				
1895	230	1912	1,123	1924		
1896	60	1914	1,850	1916	75	1921
1897	100	1913	209	1914	60	1916
	220	1918	190	1924	115	1940
1898	323	1900	250	1915	20	1923
	1,325	1924				
1899	655	1915	410	1922		
1900	230	1921				
1901	30	1921				
1902	160	1918	1,750	1919	50	1923
	220	1927	45	1936		
1903	70	1912	10	1925		
1904	400	1919				
1906	150	1919				
1917	30	1919	230	1929		

5-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
Unknown	1,360	1,110	250
TOTAL	1,360	1,110	250

6-IN. CAST-IRON UNLINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1886	1,490	1,490	0
1887	8,920	8,920	0
1888	650	0	650
1889	6,571	6,571	0
1890	432	432	0
1891	3,298	3,298	0
1893	469	469	0
1895	1,969	1,969	0
1896	6,788	5,520	1,268
1897	7,439	6,249	1,190
1898	7,396	7,346	50
1899	21,574	20,864	710
1900	34,499	33,474	1,025

6-IN. CAST-IRON UNLINED MAINS (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1901	16,181	15,395	786
1902	20,445	19,610	835
1903	17,951	17,361	590
1904	18,953	17,320	1,633
1905	15,372	13,797	1,575
1906	9,086	8,536	550
1907	12,098	12,098	0
1908	16,809	15,527	1,282
1909	20,660	20,360	300
1910	13,668	13,423	245
1911	13,160	13,160	0
1912	18,166	18,166	0
1913	16,348	15,088	1,260
1914	9,470	9,470	0
1915	12,565	12,565	0
1916	8,065	8,065	0
1917	6,980	6,930	50
1918	2,195	2,035	160
1919	5,335	5,335	0
1920	3,825	3,825	0
1921	10,300	10,300	0

6-in. Cast-Iron Unlined Mains (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1922	10,545	10,545	0
1923	9,060	9,060	0
1924	12,995	12,995	0
1925	15,070	15,070	0
1926	6,735	6,735	0
1927	11,890	11,890	0
1928	2,144	2,144	0
1929	2,372	2,372	0
1930	381	381	0
1931	443	443	0
1932	633	633	0
1933	288	288	0
1934	605	605	0
1935	294	294	0
1936	3,394	3,394	0
1938	139	139	0
1939	830	830	0
1940	1,549	1,549	0
Subtotal	448,494	434,335	14,159
Unknown	286,503	271,496	15,007
Total	734,997	705,831	29,166

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1888	650	1926				
1896	1,060	1927	208	1931		
1897	740	1918	250	1920	200	1921
1898	50	1925				
1899	710	1926				
1900	200	1917	35	1922	658	1927
	132	1930				
1901	500	1915	250	1916	36	1938
1902	480	1923	325	1924	30	1925
1903	400	1922	190	1924		
1904	650	1916	191	1917	90	1919
	702	1927				
1905	1,000	1919	575	1923		
1906	550	1919				
1908	50	1917	310	1918	350	1919
	500	1926	72	1930		
1909	300	1912				
1910	160	1924	85	1936		
1913	55	1926	1,145	1927	60	1935
1917	50	1919				
1918	160	1921				

8-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1880	1,080	1,080	0
1881	6,240	6,240	0
1884	8,400	8,400	0
1887	2,880	2,880	0
1889	2,879	2,879	0
1890	566	566	0
1891	1,585	425	1,160
1892	816	816	0
1893	4,737	4,737	0
1894	1,565	1,565	0
1895	16	16	0
1896	1,560	1,560	0
1900	1,630	1,630	0
1901	320	320	0
1902	230	230	0
1905	3,546	3,546	0
1907	300	300	0
1909	5	5	0
1912	1,181	1,181	0
1913	2,551	2,551	0
1914	700	700	0
1915	530	530	0
1918	220	220	0
1919	570	570	0
1920	30	30	0
1921	815	815	0
1922	840	840	0
1923	20	20	0
1927	140	140	0
1930	510	510	0
1931	1,098	1,098	0
1933	297	297	0
1938	7	7	0
1940	0	0	0
Subtotal	47,864	46,704	1,160
Unknown	8,456	3,406	5,050
Total	56,320	50,110	6,210

Retirements by Years

Year Installed	Feet	Year
1891	1,160	1920

10-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1870	2,160	2,160	0
1879	2,304	2,304	0
1880	1,500	1,500	0
1881	264	264	0
1882	180	180	0
1883	1,800	1,800	0
1884	24	24	0
1886	192	192	0
1887	6,816	6,816	0
1890	600	600	0
1891	1,507	1,507	0
1892	2,640	2,640	0
1893	2,280	2,280	0
1895	1,812	1,812	0
1902	190	190	0
1903	1,449	1,449	0
1907	25	25	0
1908	2,745	2,745	0
1909	40	40	0
1910	44	44	0
1912	3,759	3,724	35
1915	110	110	0
1916	3,395	3,395	0
1919	285	285	0
1924	20	20	0
1925	21	21	0
1933	626	626	0
1934	46	46	0
1940	0	0	0
Subtotal	36,834	36,799	35
Unknown	513	513	0
Total	37,347	37,312	35

Retirements by Years

Year Installed	Feet	Year
1912	35	1926

12-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1891	2,800	2,800	0
1893	2,357	2,357	0
1895	3,912	3,912	0
1897	8,512	8,512	0
1898	2,800	2,800	0
1899	16,128	16,128	0
1902	1,003	1,003	0
1903	7,958	7,958	0
1904	2,491	2,491	0
1905	6,038	6,018	20
1907	1,457	1,457	0
1908	376	376	0
1909	5,621	5,621	0
1910	60	60	0
1911	1,305	1,305	0
1912	250	250	0
1913	3,081	3,081	0
1914	402	402	0
1915	6,890	6,890	0
1916	345	345	0
1917	3,290	3,290	0
1918	225	225	0
1919	1,430	1,430	0
1920	315	315	0
1923	5,010	5,010	0
1924	6,700	6,700	0
1925	687	687	0
1926	3,010	3,010	0
1927	4,130	4,130	0
1934	11	11	0
1938	17	17	0
1940	0	0	0
Subtotal	98,611	98,591	20
Unknown	38,550	36,005	2,545
Total	137,161	134,596	2,565

Retirements by Years

Year Installed	Feet	Year
1905	20	1921

14-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1884	568	0	568
1892*	3,000	2,600	400
1893	2,520	2,520	0
1903	1,498	1,498	0
1904	1,180	1,180	0
1940	0	0	0
Total	8,766	7,798	968

Retirements by Years		
Year Installed	Feet	Year
1884	568	1893
1892	400	1919

16-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1880	13,365	13,365	0
1883	72	72	0
1885*	2,328	2,328	0
1886	1,460	1,460	0
1887	790	540	250
1888*	5,016	5,016	0
1889*	718	718	0
1890*	684	684	0
1891	2,730	2,730	0
1892	5,150	5,150	0
1893	10,740	9,745	995
1894*	36	36	0
1895	6,725	5,350	1,375
1897	3,648	3,648	0
1899	367	367	0
1903	3,004	3,004	0
1904	3,245	3,245	0
1907	980	980	0
1908	1,168	1,168	0
1909	3,392	3,392	0
1910	5,079	5,079	0
1911	885	885	0
1913	3,587	3,587	0
1914	3,570	3,570	0

Year Installed	Feet		
	Installed	In Service	Retired
1915	2,165	2,165	0
1916	3,160	3,160	0
1920	770	770	0
1921	2,545	2,545	0
1922	400	400	0
1923	465	465	0
1924	2,805	2,805	0
1925	1,590	1,590	0
1926	215	215	0
1932	12	12	0
1940	0	0	0
Subtotal	92,866	90,246	2,620
Unknown	134	134	0
Total	93,000	90,380	2,620

Retirements by Years				
Year Installed	Feet	Year	Feet	Year
1887	250	1926		
1893	435	1916	560	1920
1895	1,375	1911		

* Year purchased.

18-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1872	763	0	763
1873	85	85	0
1889	13,985	13,985	0
1890	6,290	6,290	0
1892	192	192	0
1893	11,425	11,425	0
1894	3,240	3,240	0
1895	132	132	0
1899	187	187	0
1903	4,195	4,195	0
1904	1,934	1,584	350

Year Installed	Feet		
	Installed	In Service	Retired
1907	40	40	0
1908	1,560	1,560	0
1914	4,966	4,966	0
1925	300	300	0
1926	2,110	2,110	0
1927	25	25	0
1934	3	3	0
1940	0	0	0
Total	51,432	50,319	1,113

18-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years

Year Installed	Feet	Year
1872	763	1912
1904	350	1923

20-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1891	360	360	0
1892	820	780	40
1893	8,200	8,200	0
1896*	240	240	0
1898*	504	504	0
1903	953	953	0
1904	3,168	3,168	0
1905	883	883	0
1908	11,344	11,344	0
1911	615	615	0
1913	2,752	2,752	0
1922	20	20	0
1940	0	0	0
TOTAL	29,859	29,819	40

Retirements by Years

Year Installed	Feet	Year
1892	40	1919

* Year purchased.

24-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1872	9,135	9,135	0
1887	5,100	5,100	0
1888	4,820	4,820	0
1889	2,000	2,000	0
1892	1,056	1,056	0
1893	2,767	2,767	0
1895	8,714	6,781	1,933
1898	660	660	0
1903	589	589	0
1904	1,078	1,078	0
1908	198	198	0
1909	3,000	3,000	0
1914	9,325	9,325	0
1916	40	40	0
1940	0	0	0
TOTAL	48,482	46,549	1,933

24-IN. CAST-IRON UNLINED MAINS (contd.)

Retirements by Years

Year Installed	Feet	Year
1895	1,933	1909

30-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1893	4,738	4,738	0
1894	570	570	0
1899	27,196	27,196	0
1903	495	495	0
1908	20	20	0
1910	865	825	40
1926	35	35	0
1940	0	0	0
TOTAL	33,919	33,879	40

Retirements by Years

Year Installed	Feet	Year
1910	40	1917

36-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1893	7,446	7,446	0
1898	15,176	15,176	0
1907	5,760	5,760	0
1908	16,958	16,958	0
1909	1,333	1,333	0
1940	0	0	0
TOTAL	46,673	46,673	0

48-IN. CAST-IRON UNLINED MAINS

Year	Feet		
Installed	Installed	In Service	Retired
1897	213	213	0
1908	5,230	5,230	0
1940	0	0	0
TOTAL	5,443	5,443	0

4-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1935	52	52	0
1940	74	74	0
Total	126	126	0

6-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1925	595	595	0
1926	710	710	0
1927	490	490	0
1934	216	216	0
1940	1,023	1,023	0
Total	3,034	3,034	0

8-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1934	597	597	0
1940	447	447	0
Total	1,044	1,044	0

16-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1933	53	53	0
1934	45	45	0
1940	0	0	0
Total	98	98	0

1-in. Steel Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1927	895	673	222
1933	100	100	0
1934	28	28	0
1939	1,515	1,515	0
1940	0	0	0
Total	2,538	2,316	222

Retirements by Years

Year Installed	Feet	Year
1927	222	1940

1¼-in. Steel Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1920	355	355	0
1925	60	30	30
1929	30	30	0
1934	123	123	0
1939	358	358	0
1940	0	0	0
Total	926	896	30

Retirements by Years

Year Installed	Feet	Year
1925	30	1928

1½-in. Steel Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1909	86	86	0
1920	65	65	0
1925	185	185	0
1927	425	425	0
1928	22	22	0
1929	60	60	0
1932	162	162	0
1934	108	108	0
1937	1,121	1,121	0
1939	849	849	0
1940	222	222	0
Total	3,305	3,305	0

2-in. Steel Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1914	235	235	0
1919	500	500	0
1920	135	135	0
1922	2,160	2,125	35
1923	340	340	0
1925	25	25	0
1926	10	10	0
1927	350	350	0
1928	856	856	0
1929	90	90	0
1930	130	130	0
1931	283	283	0
1932	44	44	0
1933	211	211	0
1934	187	187	0
1940	0	0	0
Total	5,556	5,521	35

2½-IN. STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	22	22	0
1940	0	0	0
TOTAL	22	22	0

3-IN. STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	8	8	0
1940	0	0	0
TOTAL	8	8	0

6-IN. GALVANIZED STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1895	40	40	0
1940	386	386	0
TOTAL	426	426	0

8-IN. GALVANIZED STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1893	203	203	0
1897	52	52	0
1940	0	0	0
TOTAL	255	255	0

10-IN. GALVANIZED STEEL MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	125	125	0
1940	0	0	0
TOTAL	125	125	0

1½-IN. STEEL CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1936	360	360	0
1940	0	0	0
TOTAL	360	360	0

2-IN. STEEL CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	496	496	0
1929	1,888	1,888	0
1930	437	437	0
1931	234	234	0
1932	505	505	0
1933	449	449	0
1934	141	141	0
1936	961	961	0
1938	195	195	0
1939	237	237	0
1940	483	483	0
TOTAL	6,026	6,026	0

1-IN. STEEL LEAD-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1939	167	167	0
1940	0	0	0
TOTAL	167	167	0

1¼-IN. STEEL LEAD-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1939	160	160	0
1940	0	0	0
TOTAL	160	160	0

1½-IN. STEEL LEAD-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1937	253	253	0
1940	0	0	0
TOTAL	253	253	0

2-IN. STEEL LEAD-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1931	403	403	0
1939	80	80	0
1940	0	0	0
TOTAL	483	483	0

2-IN. WROUGHT-IRON MAINS*

Year Installed	Feet		
	Installed	In Service	Retired
1898	1,750	1,750	0
1911	250	250	0
1940	0	0	0
TOTAL	2,000	2,000	0

* 220 ft. of 2-in. wrought-iron pipe retired in 1916; date of installation unknown.

8-IN. WROUGHT-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1912	120	120	0
1940	0	0	0
TOTAL	120	120	0

10-IN. WROUGHT-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1916	125	0	125
1940	0	0	0
TOTAL	125	0	125

Retirements by Years

Year Installed	Feet	Year
1916	125	1928

16-IN. WROUGHT-IRON MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1897	110	0	110
1940	0	0	0
TOTAL	110	0	110

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1897	65	1933	45	1934

18-IN. KALAMEIN MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1872	3,580	0	3,580
1940	0	0	0
TOTAL	3,580	0	3,580

Retirements by Years

Year Installed	Feet	Year
1872	3,850	1911

20-IN. KALAMEIN MAINS

Year Installed	Feet		
	Installed	In Service	Retired
1872	3,905	0	3,905
1940	0	0	0
TOTAL	3,905	0	3,905

Retirements by Years

Year Installed	Feet	Year
1872	3,905	1912

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

WELLS AND GROUND WATER

Underground Waters. EDWARD B. BAILEY. Surveyor (Br.) **104:** 481 (Aug. 24, '45). Well digging brought emancipation to man from thralldom of river banks. For centuries building development of Greater London restricted to water-bearing terrace gravels flanking Thames. Underground analogues of surface streams and lakes enormously extended bodies of water, minutely distributed throughout permeable rocks; streams ooze slowly; lakes stand practically stationary. Permeable rocks will share water with well dug into it; impermeable will not. If borehole drilled through impermeable cover into confined underground lake, water will tend to rise in borehole to level of water alongside cover. Well of this type called "artesian." In 18th century bores sunk through London clay to underlying chalk actually overflowed. Since then many bores developed. Standing water level in wells has been depressed to more than 100′ below sea level. Long-continued reduction of water level shows we draw on capital. Rough rule in Britain that of all rain which falls, ⅓ evaps., and of remaining ⅔, one-half, in dist. of permeable outcrops, goes by percolation to join ground water, while other half runs off in surface streams. Total annual water requirements of man, domesticated beast, irrigated crop and industry, for country as whole, amt. to some 4,500,000–5,000,000 mil.gal. As matters stand, mobilization of surface waters accts. for 4,000,000–4,500,000 mil.gal. per yr. Corresponding figure for underground waters is some 200,000 mil.gal. Most of Britain has been mapped and often possible to tell whether well site lies on permeable or impermeable outcrop. This is geologists' contribution. In questions of water supply qual. of importance. Underground water less risky than surface water. Noxious microbes have to run gantlet of gelatinous film of harmless indigenous micro-organisms. Consideration for rights of fish has materially helped London to prosper on dild. sewage effluent of Windsor, Windsor on that of Reading, and so on up Thames. Permeable rocks often yield fresh water from depths below sea level. Slowly descending columns of fresh water displace subjacent layers, whether these be fresh or salt. In pumping deep bore near coast care has to be exercised not to use up too rapidly accumulated reserves of fresh water. Hardness is good for drinking, bad for washing, good for breweries, bad for boilers. Underground water in Wet West may be contained in superficial deposits, thick permeable formations or mines. Water in abandoned coal and metalliferous mines may have commercial applications and may even be suitable for drinking. England, east of Wet West, still relies largely on surface waters. Rural areas attracting attention today. Dist. that cannot reach supply should be coupled with adjoining dist. more favorably endowed. Little public control of underground water in Great Britain. Competition has led to big calls upon hydrological capital. No scheme of artificial replenishment or of maint. through restriction could be adopted except as designed for public, and not individual, profit. Measures will be taken before long to regulate development of underground water resources.—*H. E. Babbitt.*

The Protection Against Pollution of Water Supplies Drawn From Ground Water and Spring Water. E. F. HOFMANN. Gas-u. Wasser. (Ger.) **84**: 709 ('41). Phys., chem. and biol. characteristics which render water unfit for domestic use described. Measures discussed which should be taken to prevent poln. of ground water by surface water. Very little lateral movement of ground water and inorg. substances which have entered water carried only in direction of flow of water. F. Schübel considers that in flowing ground water it may take 50 to 60 days for moderate amt. of polg. matter to become sufficiently dild. to be unobjectionable. Therefore necessary to det. rate of flow of ground water and to establish around water works protected area of such size that water takes at least 50 days to travel from edge of area to works. Methods of detg. rates of flow of ground water discussed. Decompn. of org. matter and destruction of pathogenic bacteria in rain water passing through soil discussed. Ground water at depth of several meters below almost impermeable strata seldom contains bacteria. Surface water, carrying org. matter, may percolate through beds of rapidly flowing streams on which there is no mud; such org. matter will not be decomposed. Removal of bacteria by soil cannot be mainly mech. action; it is possible that some bacteria might be retained by clay but likely that bacteria destroyed by unsuitable environmental conditions. Where upper layers of rock permeable and where there is no covering of humus, pathogenic bacteria may enter ground water and remain alive for considerable time; in such situations poln. of ground water by sewage and other org. matter should be prevented over area of such size that ground water traveling at its max. rate would take at least 60 days to pass from edge of area to water works. Where upper layers of rock impermeable and unfissured protected area of 100 sq.m. around deep wells and springs and of 500 sq.m. around shallow wells sufficient. Cost of maintg. protected area may be prohibitive for small water works and in such cases centralization of water supply preferable. When subsequent increase in water supply likely to be required, area of protected land should be large enough to allow for probable increase in area of intake plant and may be divided into 2 zones; regulations for outer zone need not be at beginning so stringent as those for inner zone. Steps to prevent poln. at works during and after constr. described.—*W.P.R.*

Physical, Chemical and Bacteriological Changes in Ground Water Due to Unfiltered Surface Water. W. AUSTEN. Water. *A Yearbook for Water Chemistry and the Technic of Water Treatment.* **XV**: ('41–'42). Verein Deutscher Chemiker. Verlag Chemie, G.m.b.H. (Ger.) ('42) 368 pp. Water supply of Breslau obtained until '05 from Oder, but because of increasing poln. of river at beginning of century this source of supply abandoned and ground water used. In '06 serious shortage of water; supply supplemented by laterally and vertically filtered river water. Oxygen consumed from permanganate by, and content of chloride in, Oder water shown in graphs for period '09–'38. During this period content of chlorides in river water and permanganate oxygen demand have increased owing to indus. poln. In order to investigate effect of lateral filtration, 50 wells, about 12 m. deep, constructed along bank of Oder, at distance of 50 m. from river. In chem. compn. water from these wells appeared to be mixt. of ground water and surface water. Table given showing contents of chloride, iron and manganese; total and carbonate hardness; and permanganate oxygen demand of well water from '10 to '38. Figures show that effect of surface water is to increase content of chloride and oxygen demand, and to decrease amts. of iron and manganese. During period of years originally satisfactory bact. qual. of water deteriorated. Number of total bacteria and coliform bacteria tended to increase after severe frost and after flooding of river. In '34, however, increasing bact. poln. of water in some wells could not be accounted for by these causes. Tests showed that water in some wells contained less iron and more bacteria and had different temp. from water in other wells. Appeared that surface water entering some wells through permeable soil without adequate filtration. Investigations also made on horizontal filtration and found that river water entered many wells almost unchanged. In '06 water in most wells became unusable. Control of flood water and use of seepage ponds connected to river Ohle to increase ground water supply improved water in some wells. Compn. of water of Ohle changed very little until '34 when increasing poln. of Oder caused deterioration in qual. Artificial increase in supply of ground water caused considerable changes in its compn. Hardness and total content of iron increased but amt. of dissolved iron tended to decrease. Amt. of

manganese seldom increased and amt. of org. matter increased only slightly. In times of drought, necessary to supplement supply with small amts. of chlorinated water from Oder. In '34 canal brought into operation carrying water from Oder to Ohle through lake with capac. of almost 500,000 cm., which serves as sedimentation basin. Bacteria largely removed in this basin. Extensive tests carried out in '38 to study effects of filtration through soil on phys. and chem. properties of ground water. Effects of addn. to Ohle of water from Oder on iron in ground water described. Methods required for removal of iron at treatment plants given. Suggested that Oder water should be given prelim. treatment before being mixed with Ohle water, so that qual. of ground water would not be affected.—*W.P.R.*

Supplementing Ground Water—Physical and Chemical Observations. W. AUSTEN. Gas-u. Wasser. (Ger.) **82**: 606 ('39). At Breslau supply of ground water artificially increased by seepage from ponds. Observations made on rate of percolation and on changes taking place in bact. count and temp. of water between pond and wells from which supply drawn. Pond observed about 40 m. from series of wells. Rate of flow from pond to wells detd. by adding sodium chloride to water in pond. Samples of water withdrawn through pipes driven into soil at various points between pond and wells. Record of climatic conditions kept and sieve anals. made of surrounding soil. Reduction in numbers of bacteria in water began to occur at distance of few meters from pond. Temp. of water in soil fell to that of water in wells at distance of 30 to 40 m. from pond. Rate of horizontal movement of water in soil during periods of normal operation and normal meteorological conditions 4.5 cm./hr. During periods of normal operation water from pond reached wells in 42 days.—*W.P.R.*

Deep Water Well at the Jayhawk Ordnance Works in Cherokee County, Kan. G. E. ABERNATHY. Kan. Geol. Survey Bul. **47**: Part 3: 77 ('43). Mississippian rocks of southeastern Kansas contain abundant supplies of water, but because of its high mineral content water in some areas not suitable for domestic supplies. Water in overlying Cherokee shale acid and may cause corrosion of uncemented iron casings in wells. Capac. of wells in limestone or dolomite, or in sandstone cemented with calcium carbonate, can be increased by treatment with acid. Capac. of well at Jayhawk ordnance works in Cherokee County, Kan., has been increased to more than 4 times its original capac. by this treatment. Anals. of 13 waters given.—*W.P.R.*

Abyssinian Tube Wells. COLIN JOHNSTON ROBB. Wtr. & Wtr. Eng. (Br.) **47**: 271 (June '44). Abyssinian, or driven-tube well, one of readiest means of obtaining ample water supply where no rock or incompressible clay met. Well best suited for tapping water-bearing strata to depths up to 20′, though author has seen them driven up to 100′ in depth. Yield of 2″ tube will be up to 600 gph. (Imp.).—*H. E. Babbitt.*

The Assessment of Percolation. P. G. H. BOSWELL. Wtr. & Wtr. Eng. (Br.) **46**: 466 (Nov. '43); (*Abstracted*, Jour. A.W.W.A. **36**: 231 ('44). *Discussion. Ibid.* **47**: 62 (Feb. '44). S. R. RAFFETY: Probably fair consensus of opinion that 10″ of percolation is as much as can be expected. Undoubted fact that summer rain does not affect percolation so that any percentage of annual rainfall would vary much according to its incidence. PHILIP PORTEOUS: Percolation gage not such a worthless piece of app. as author would have us believe. If carefully constructed it should give at least comparative results with tendency to err on low side. F. H. EDMUNDS: Schedule of areas of underground waters which author proposed would be valuable but its prepn. would involve considerable collection and collation of data and would take several years. Infiltration from streams something different from percolation in replenishment of underground water. Latter part of rainfall and related to immediate locality. EDGAR MORTON: Author made no mention of losses due to vegetation. Speaker has never regarded 10″ as anything more than convenient yardstick by which to express amt. of percolation in given area. Would be far more scientific to express percolation as percentage of rainfall rather than definite fig. of so many inches. CHARLES LAPWORTH: Where data available, preferable to rely on evidence of effect of pumping from existing wells rather than on any calcns. based on assumed fig. for percolation. W. N. MCCLEAN: Rain gage well sited accepted as satisfactory measure of rainfall on that site and if there are sufficient gages to provide daily rainfall fig. over whole area, fig. of area rainfall can be accepted and cease to be matter

of expert opinion. Percolation gage as at present designed appears to measure actual percolation provided there is no runoff. J. GLASSPOOLE: Percolation gage can do no more than give measure of amt. of rain percolating through gage. Evapn. tank gives measure of evapn. from free water surface. Inland Water Survey publishing before war details of both rainfall and runoff for number of areas. J. F. HASELDINE: Figs. of Lee watershed quoted by author, made prior to '20 and based on Fields weir gagings, valueless. In '20 investigation of Fields weir by E. P. Hill for Lee Conservancy Board reported figs. purporting to show quant. of water passing this weir quite valueless. W. S. BOULTON: Citation of large number of percolation figs. given by engrs. and geologists during last 50 yr. when used for comparison may be misleading if figs. quoted separated from context. Author proposes to take 40%, or in some cases 50%, of rainfall as pilot fig. for estg. percolation. Whatever pilot fig. used, investigations in any area roughly those which Inland Water Survey undertook some years ago to direct and carry out for whole country. D. HALTON THOMSON: Disagree that estimation of percolation should start from provisional fig. expressed as percentage of annual rainfall. Percolation essentially residual phenomenon. Annual rainfall variable factor. Annual evapn. loss very nearly const. Avg. percentage percolation must vary in same way with geographical distr. of avg. rainfall. R. C. S. WALTERS: We should beware of confusing porosity with percolation, and being drawn into arguments concerning inches of percolation without collecting areas being definable. *Author's Closure:* Would urge those who are loath to give up fig. of 10″ for percolation to use it, if they must do so, for their own domestic ests., but not to risk imperiling developments during reconstr. by putting forward theoretical computations based on it in order to restrict their neighbors' efforts.—*H. E. Babbitt.*

Ground Water Geology at Natchitoches, Louisiana. J. G. MAHER & P. H. JONES. U.S.G.S. Prelim. Rpt. (May 1, '44). Series of exploratory test wells in undeveloped Sparta and Wilcox sands, southwest of city, drilled before considering further a possible impounded surface supply to augment present depleted ground water source, disclosed soft water in quants. to yield at least 1 mgd. from 3 to 5 properly developed sites. Prelim. rpt. describes geol. features of area and summarizes information revealed by testing program.—*A. A. Hirsch.*

Geology and Ground Water Resources of Cimarron County, Okla. STUART L. SCHOFF & J. WILLIS STOVALL. Okla. Geol. Survey Bul. *No. 64* ('43). Mainly geol. anals. of 48 well waters given; range of mineral content, in ppm., follows: total dissolved solids, 234–1649; SiO_2, 11–53; Ca, 5.4–51; Mg, 4.7–38; Na (3 detns.), 18–32; K (3 detns.), 2.8–3.8; Na + K, 10–375; HCO_3, 120–724; SO_4, 14–420; Cl, 3.9–145; F, less than 0.1–3.8, avg. 2.0; NO_3, less than 0.1–18 (an exceptional well gave 638); total hardness as $CaCO_3$, 33–348, with 2 wells giving 682 and 1088, resp. Effect of F on teeth of county's children discussed; of 15 children examd. at Boise City (F = 0.8–2.0 ppm.), 5 had "borderline" cases of mottled enamel.—*C.A.*

Construction of Wells for Public Water Supplies. HERBERT GROVE. Can. Engr.—Wtr. & Sew. **81**: 9: 25 (Sept. '43). Knowledge of geology of locality important. Test holes should be 4–6″ and should be cased to enable study of drawdown and yield. Chances for contamn. numerous. Well logs advisable, taking samples every 5′ or more frequently when different material encountered. Outside water-tight casing should extend at least 10′ below surface and 10′ or more below static ground water level, depending upon possibilities of poln., and should be seated securely in impervious formation if possible. Casing should extend 6″ above pump room floor and latter preferably at least 24″ above ground level. Cast iron most desirable material and secondhand casing should never be employed. Annular space between drill hole and casing should be grouted. Good grout can be prepd. with 1 cu.ft. of fresh cement and 4–5 gal. clean water, admixtures of up to 10% hydrated lime by vol. being advisable. Suggestions of Wisconsin State Bd. of Health re grouting included.—*R. E. Thompson.*

Plan to Regulate Florida Drilling. ANON. The Driller. **17**: 6: 15 (June '43). Proposal to regulate drilling and use of fresh water wells in Fla. introduced in State Senate. Principal provisions require: (1) filing statements with state geologist on all wells over 200′; (2) drillers to supply state geologist with drill

cuttings for each 20′ depth and 24-hr. notice of intention to abandon well; (3) driller to plug or case abandoned well to prevent escape of oil, gas or water from one stratum into another of different character; and (4) make driller responsible for preventing gas, oil or water mixing, when practical.—*Ralph E. Noble.*

Artificial Flooding Builds up Ground Water Yield. DALE L. MAFFITT. W.W. Eng. **96**: 1230 (Nov. 3, '43). Water supply for Des Moines, Iowa, taken from Raccoon R. Valley. River tends to keep layer of sand and gravel satd. with water. Water collected by infiltration gallery system parallel to river. To increase yield, basins along river flooded by pumping from river. Various basins formed by building levees from earth removed from ground surface of basins. Because of differences in surface soils, underlying sands and distances from galleries, varying yields obtained from different basins. This has resulted in development of schedule of use. To accomplish this, system of weirs and canals constructed. Total of 64½ acres included in flooding area. Area may be flooded to depth of 3′ or 4′. Three low-lift pumps, having a total capac. of 20 mgd., pump water from river to basin. Normal avg. capac. of collecting galleries about 18 mgd., but rates as high as 25 mgd. maintd. Land flooding in Des Moines has served as immediate source of supply in times of drought as well as limited means of water storage.—*C.A.*

Investigation of Ground Water Pollution. *Part I. Determination of the Direction and the Velocity of Flow of Ground Water.* BRIAN R. DYER & T. R. BHASKARAN. J. Ind. Med. Research **31**: 231 (Oct. '43). Field expt. conducted to discover veloc. and flow direction of ground water. Exptl. field consisted of borehole, 20′ × 16″ diam. as central charging well. Caving of sides prevented with bamboo matting and later with concrete casing. Latter was 12″ spun-concrete pipe with ½″ holes spaced 6″ c. to c. Two sets of wells encircled central borehole at 5′ and 10′, resp. In 5′ zone 18 wells at alternating shallow (12′ 3″) and medium (15′ 3″) depths, 2′ apart. In 10′ zone, 44 deep (18′ 3″) wells spaced 1½′ apart. Direction-of-flow expt. occurred from June to Sept. '40, while veloc.-of-flow expt. conducted from Sept. '40 to Jan. '41. Two kg. of salt added June 3 to central well and contents thoroughly mixed by air under 50-lb. pressure 20 min. When salt stream dropped to normal, central borehole rebored to 19′ and 10 kg. more salt added. Sept. 21. Soil at exptl. site clay-silt down to 16′ with medium-sized sand below. Phys. characteristics within Hazen's limits for applying theoretical formulas. Because of caving in, central borehole salt movement conspicuous in shallow strata only. Flow direction in all 3 strata along one well (MJ). During expt. on veloc., great fluctuation in water table and slopes. No caving occurred and salt flowed freely through all strata. At height of monsoon, flow swung to one side briefly but soon returned to original direction which was more or less same in both expts. Evidence from medium and deep wells indicated max. flow veloc. of 2½′ per day. No significant difference between velocs. in deep and medium strata, but slower in shallow than in other two. Salt flowed from charging well downward and somewhat laterally while water entered well, dilg. surface content. Const. proportional decrease in salt concn. in borehold noted. Estd. 1 gpd. flow from latrine when water table at 8′. Close correlation found between sand transmission const. and veloc.—*Ralph E. Noble.*

Ground Water—Its Development, Uses and Conservation. The Construction of Sanitary Wells. ANON. Johnson Natl. Drillers' Jour. **15**: 1 (July–Aug. '43). States' rules under which wells may be built not needless interference as nothing more dangerous to health of community than pold. well. Some states establish distance well must be from sewer or similar source of poln. This distance varies from 100′ to 1000′. All states require casings to be tight and many stipulate precautions necessary at surface. Natural filtration discussed and instances cited where ground soil so loaded with impurities that poln. supplied to water percolating downward. Surface waters or shallow ground waters more liable to be contamd. than deep rock water. Springs and even deep rock wells not above suspicion. All newly constructed wells should be sterilized. In constr. of well for domestic water supply something more than mere drilling necessary. Space between drill hole and casing must be closed or sealed. Cement grout recommended. Grouting technic developed by Div. of Well Drilling, Wisconsin State Bd. of Health, given. Patented grouting process employed by Halliburton Oil Well Cementing Co. described. Details of grout-

ing with liner pipe given. Reader referred to article for details on grouting. Grouting jobs of 150′ or less handled with equip. that can be found in almost any well driller's back yard. Most drillers, never having done a grouting job, are afraid of it and discourage such jobs. Where larger quants. of grout required, some form of mech. mixer required. Continuous type mixer most satisfactory. Mixing must not stop until grouting completed. Any type of slow-speed reciprocating or diaphragm pump will be suitable for pumping grout. For wells constructed in drift formations clay mix will do just as good a job as cement. Clay cannot be used in rock wells where more stable grout must be used. Some companies have exptd. with bituminous base but technic more or less private.—*C.A.*

PUMPS AND RELATED EQUIPMENT

Boosters for Water Supply Systems. J. V. BRITTAIN. Machinery Lloyd. **17**: 37 (May 12, '45). Need for boosting may be due to: (a) point at which water is required being at higher level than that to which water would naturally flow; or (b) distributing mains being too small, with result that friction loss reduces available head to such extent that insufficient flow obtained. Booster is some form of pump which takes water in at low pressure and carries it forward at higher pressure. Normally it is pressure augmenter in series with main feeder. Main objection to series booster is that when pump in operation demand for water may vary from practically no load to full load. Use of elevated reservoir is perhaps simplest arrangement for supplying high-contour loads. Hydrostat is water-operated pump which can be used as booster without any outside power connections, providing main flow of water is such that fall of pressure in operating cylinder not likely to cause trouble further along main. Where there is excess pressure in main this scheme can be used to force proportion of water to height greater than that from which water originated. Use of compressed air has been one of most successful methods of boosting and many villages now being supplied on this principle. Possible that use of boosting pumps may result in use of smaller mains than would be possible with gravity flow.—*H. E Babbitt.*

The New Chertsey Pumping Station of the Woking Water and Gas Company. J. DALRYMPLE. Wtr. & Wtr. Eng. (Br.) **48**: 27 (Jan. '45); (*Abstracted*, Jour. A.W.W.A. **37**: 7: 707 ('45).) *Discussion. Ibid.* **48**: 213 (May '45). B. L. MCMILLAN: Prelim. investigation of relative costs of motive power in pumping stations, before deciding which is to be adopted, always compensates for trouble taken. Oil plant shown to be most economical in case of new Chertsey plant. A. F. ILSLEY: Difference between estd. cost of £7600 and final cost of £11,088 for oil engine plant considerable. H. F. CRONIN: Many cubist bldgs. recessed at top and on some of them considerable amt. of green slime appeared, due to rain running down walls. Older pumping stations had copings 3′ or more wide. These probably threw off rain water so that bldgs. maintd. good appearance. Provision for employees should include place for bicycles, as men would otherwise lean them against walls, thereby chipping plastering. Locker space should be provided, otherwise old boots and empty milk tins left about works. If installation of oil-proof floor omitted, floor almost ruined after first overhaul of diesel engine. A. B. E. BLACKBURN: Seems optimistic to depend on one unit for principal pumping station, especially high-speed diesel engine. If plant had been in duplicate capital charges item would have been considerably in favor of electricity. If 2 sets of 1 mil.gal. each and 1 of 2 mil.gal. had been installed, plant could have given high eff. over whole range from 1 to 4 mil.gal. No item in table of costs for repairs. Labor costs shown about equal for diesel and elec. plants. Table gave impression of unduly favoring diesel plant. S. R. RAFFETY: Bldg. and foundation costs are less when using elec. plant than for diesel or steam plant. With diesel engines maint. costs higher. W. H. AUSTIN: We have been unable to obtain wood for shuttering for roof and other constr. and have had to resort to metal forms. Like Mr. Ilsley, we have experienced difficulty with big end bearings. Our station bldg. had imitation stone facing; instead of green slime there was very nasty discoloration. It was cubist bldg. *Author's reply:* Contractors, tired of awaiting wood forms, used bricks

with concrete placed between for walls. No trouble with big end bearings. Estd. costs quite reliable. If one took into acct. cost of auxiliary machy. and pipe work and fact that delay occurred before final tenders received, figures compared reasonably with actual costs. Cost highest for electrically driven plant. Figure in table did not include 37% on-charge. Oil engine not duplicated because in itself it formed duplicate plant. Well on top of bldg. in which ventilators situated. Coping slopes inwards to well, so that rain does not flow down walls. Conveniences for employees include mess room and lavatory. Ample space available elsewhere on works for storing bicycles and men's equip. Would have been necessary to spend £2000 on cable, switches and transformer to bring electricity to works.—*H. E. Babbitt.*

The Evolution of the Water Works Booster Pump. J. P. HALLAM. Wtr. & Wtr. Eng. (Br.) **48**: 59 (Feb. '45). First elec. driven booster station in Manchester put into service on distr. main in '19, followed soon afterwards by 2 more on practically identical lines. Used to increase day-time pressure of 25 psi. to 75 psi. and were operated automatically using pressure gage control. Two main principles evolved in automatic boosting, namely, pressure control by gage and flow control by water meter. First gives advantage of regulation of pressure of supply and control of number of pumps on load. Suitable for relatively small outputs up to about 1000 gpm. Second developed for larger outputs. Where variable speed essential, tendency to adhere to what is known to be reliable and this has resulted in attachment to d-c. drive. Where const. speed drive sufficient, plain a-c. motor quite satisfactory, but preference given to wound-rotor type because of greater control over acceleration leading to steadier hydr. conditions. Where water supply drawn from mains of considerable length, pressure surges will occur at starting and stopping. In automatically operated station having pressure gage control, air vessel on delivery side will have tendency to limit surges on delivery mains. Use of suitable reflux valves of great importance when number of centrifugal pumps operating together in parallel. Early pumps fitted with ring oil-lubricated, sleeve-type bearings, which are still fitted on larger pumps. This type practically trouble free, only complaint in regard to use being occasional leakage of oil, which sometimes proves difficult to overcome. High-voltage switchgear and equip. give very little trouble, although usual to fit various types of relays to high-voltage circuit breakers to interrupt supply in case trouble develops. Principle of assembling motor starters and possibly water metering cubicles into unit type control boards considered to be advance in design; more particularly for larger stations. *Discussion. Ibid.* **48**: 218 (May '45). H. R. LUPTON: In addition to methods of control mentioned by author, there is type in which pumps started and stopped by clock, it being known that addnl. water required at certain times of day. Another ingenious scheme was installation on check valve of arm carrying a tilting mercurial switch. When any pump started, relay also started, which, if allowed to continue, shut pump off again within 1 min. If, during that minute, check valve opened, it tilted mercury and stopped relay. Thus, if pump tried to start and water did not flow, pump would stop. Another device started all available pumps if pressure fell to extent it would fall in event of fire in dist. In case of zone which varies in pressure requirements water works might save power now expended in pumping all water to highest part of zone by installing pumping station to lower head so that only necessary fraction of water pumped to higher head. In comparison between pressure control and flow control, available data show that consumption of power in case of flow control unlikely to amt. to more than half expenditure demanded by pressure control. In connection with true boosting, as distinct from repumping, much to be said for control by flow. Assuming interest and sinking funds 3.5%, life of main 80 yr., of pumping plant 25 yr., and power 0.75*d* per unit, then in case of 30″ main not economical to duplicate it until veloc. is 5 fps., and, if used only half time, not until veloc. reaches about 6.5 fps., and 0.1 time, 12 fps. W. E. WYATT MILLINGTON: At one pumping station arrangement was such that when fire engine came along road man dropped off, smashed window, pushed regulator over increasing pressure. Pressure drop required to accelerate flow through pipe independent of diameter. Roughly acceleration of 1 fps./sec. requires pressure drop of 1 psi. in pipe about 75′ long. Would be better for author to state that no pumps devoid of end thrust, although on paper they may appear to be, than to state that not all pumps

devoid of end thrust. K. W. MACNEE: Starting period of direct-on started squirrel cage motors for driving pumps under control of motor designer. Time-torque characteristic of motor can be matched to pump. Method is to be preferred either to star-delta or auto-transformer starting, where starting done in 2 steps. Squirrel-cage motors can be designed for starting current of not more than 4 times full-load current when direct-on started. *Author's reply:* In automatic pumping stations not advisable to have too many automatic features for solving particular problem. One must not attempt to alter 2 unknowns at one time. Not advisable to have too many pumping stations, repumping stations or booster stations on gravitational supply. Well to allow gravitational forces to supply dist. without interference by mech. means. Time to differentiate between booster station and increased size of main is when veloc. through main increases by 50%. Pressure control is all right for small quants., but at about 1000 gpm. flow control has certain distinct advantages. Boosting stations established in order to tide over until it becomes profitable or possible to lay mains to supply under gravity head.—*H. E. Babbitt.*

Oil Engine Development and Research. C. H. BRADBURY. Wtr. & Wtr. Eng. (Br.) **48**: 287 (June '45). Oil engine conceived toward end of last century by Akroyd Stuart in England. Modern oil engine, often mistermed "diesel," logical development of Akroyd Stuart. Original Stuart principle revived about '06. In '20's Bosch Co. introduced their revolutionary pump and injector. From '20 onwards marine field saw steady decline of blast injection diesel engine and increasing trend toward single-acting and double-acting, two-stroke, solid injection engine, together with opposed type of piston as exemplified by Doxford. Trend of past 50 yr. of progress has been: (1) increase in eff. due to steadily increasing compression ratio, with result that specific fuel consumptions have fallen from 0.9 to 0.36 lb./bhp./hr.; (2) gradual improvement in qual. of fuel injection equip. and increase in engine speed; (3) reduction of engine wt.; (4) greater reliability due to improvements in materials, fuel oils and lubricants; and (5) emergence of combustion turbine from exptl. stage to semi-commercial application for jet propulsion and to its established application for turbo-charging. Noticeable trends in present-day outlook: Although compression pressures rose to 400 psi. in '14 and '15, little increase since that date because compression pressures must be high to obtain high temp. at which to inject fuel and exhaust temp. must be low. This law is one of diminishing returns. Theoretical eff. can be increased by increasing compression ratio but only at expense of higher pressures, increased wt. and reduced mech. eff. Gradual development in bmep. (brake mean effective pressure) from 60 psi. in pre-Great War days to present-day 80 to 90 psi. Limit of output with atm. induction is on horizon. Little advance will be made beyond 120 psi. bmep. Kadenacy system of self-induction has made commercially possible 2-cycle engine ratings of 80 bmep.; equiv. to 160 bmep. in 4-cycle rating. In large engines oil injected 15° to 20° B.T.C. through multi-hole sprayer which may have anything up to 8 holes from 0.012 in. in diameter upwards and intermingling of fuel and air particles results from disturbance caused in combustion chamber by passage of sprays through highly compressed air. For high-speed engines this method of seeking out air by means of fuel jets not satisfactory because of small size of combustion chamber and fact that impracticably small jets would have to be used. Gradual increase in speeds and ratings has brought in its train difficulties with materials and lubrication. Look into future shows 4-cycle, normal induction engine has field to itself in small, high-speed engine class. In class of medium-speed engines 300- to 600-rpm. normal induction, 4-cycle engines, real fight will be between turbo-charged, 4-stroke and Kadenacy 2-stroke with mechanically-driven blower. In large engine class, 2-stroke being challenged by medium speed class with reduction gearing. Combustion turbine possesses several unique advantages over reciprocating counterpart. Vibration and balance problems, 2 or 3 bearings with oil at low temp. all that have to be catered for; and it can burn lowest grade fuel. In spite of low eff., combustion turbine will make considerable progress in field at present occupied by slow- and medium-speed engines.—*H. E. Babbitt.*

Automatic Control of Pumps by Static Head Variations. A. D. STUBBS. Wtr. & Wtr. Eng. **47**: 495 (Nov. '44). When reservoirs situated inconveniently relative to pump house, automatic starting and stopping of pump normally requires at least one elec.

conductor from reservoir to pump house. System expensive if linear distance considerable and line failures not unknown. In theory mercury column balanced against static head will give visual indication of reservoir contents. By inserting contact rod in mercury-filled glass tube, automatic control can be obtained electrically. Pipeline surges and pressure higher than static during pumping period renders balanced mercury alone impracticable. Difficulty can, however, be readily overcome by combining "hold-on" and "hold-off" magnets, together with thermal switch and pressure gage. Equip. inexpensive and foolproof and has added advantage that if main pressure falls under heavy consumption, pump comes into operation immediately and augments available storage and pressure. Where electrically started internal combustion engines drive pump, system can be used with small battery taking place of main transformer.—*H. E. Babbitt.*

A Borehole Pumping Station in Northwest England. ANON. Wtr. & Wtr. Eng. **47**: 489 (Nov. '44). Rural council's dist. has normal pop. of 30,000 and covers area of 90 sq.mi. It supplies 4000 pop. in 3 adjoining dists. In addn. to surface springs council has borehole tested to yield 1,800,000 gpd. (Imp.). Borehole is 23¼" in diam. for 500' and 17⅝" in diam. for further 250'. Lined with steel tubes for first 20' only. Hole heavily fissured for first 400'. "Major" scheme includes development of another borehole to yield 3 mgd. (Imp.) and constr. of 3-mil.gal. (Imp.) reservoir. "Minor" scheme, intended for war period only, includes borehole already sunk, use of existing water tower with capac. of 70,000 gal. (Imp.) with laying of part of 16" main required by "Major" scheme. In practice scheme works well. Two councils mutually assist each other and in emergencies take over full supply to each other's dist. Borehole pump built in two sections, each contg. 4 stages. Ultimate duty under "Major" scheme is 75,000 gph. (Imp.) against total head of 564'. Driving motor develops 300 hp. Pumping station is of brick and artificial stone with tiled roof. Operations commenced on Mar. 9, '42.—*H. E. Babbitt.*

Ingenious Measuring Devices in Use at Woodstock (Ont.) Water Works Plant. J. R. SULLIVAN. Eng. Cont. Rec. **57**: 26: 12 (June 28, '44). Supply derived from springs and well, with combined capac. of 3.74 mgd. In '43, max. pumpage 2.72 mgd. and avg. 1.84, equivalent to 120 gpd. per capita. There are 222 hydrants and 3873 services, only 187 of latter metered. To warn operators to cease pumping from springs when water colored, alarm provided actuated by photo-elec. cell located at one end of 5' length of 5" pipe fitted with plate glass ends through which water drawn by injector. Automobile sealed-beam headlight used as source of light. Two storage reservoirs, of 1.25- and 0.75-mil.gal. capac., resp., situated on hill over 1 mi. from pumping plant. Water level readings transmitted to latter by homemade device consisting of float attached to hinged arm with Ag contact at opposite end which passes in 75° arc over series of Ag contacts on resistance connected by single 6646', No. 8, bare Cu wire to 110-v. circuit in station, std. 5-amp. ammeter graduated in feet and protected by fixed resistance and fuse being used as level indicator.—*R. E. Thompson.*

The Use of Centrifugal Pumps in Water Supply Practice. S. MCCONNEL. Civ. Eng. (Br.) **39**: 83 (Apr. '44). Only in case of high heads and low capacs. or when capac. in gpm. less than head in ft., can use of reciprocating pump be justified. Rapid reduction in cost of elec. power in all parts of world has led water works authorities to utilize such sources where available. Normal head-quant. characteristic for centrifugal pump drops rapidly and is employed mainly in endeavor to prevent overloading of prime mover. In most cases conditions such that pumps can be run at const. speed which involves most economical operating conditions. Now that 3-phase alternating current almost invariably used when power has to be transmitted any distance, variation in speed can be economically made available only by use of comparatively expensive a-c. commutator motors. Squirrel-cage induction motor, due to its simplicity, low cost and ease of control, most commonly used but its heavy starting current makes it unpopular with power companies. In all cases of motor-driven pumps motor horsepower should be about 50% in excess of that theoretically required for pumps up to 2 hp. to 10% for 75 hp. and over. One great advantage of elec. driving is that frequently pumps can be operated during hours of light power demand when power companies will often give

reduced rates owing to improved load factor. One dangerous state of affairs that often requires attention in case of large pumps working with high velocs. and that is rapid changes in pressure which may occur when pump closing down. This appears to be most effectively dealt with by cone valves arranged to open slowly as pump comes into operation and to close gradually after pump stopped. Within certain limits, say 10%, impellers may be cut down in diam. to suit reduced conditions of head and discharge, and in other cases capac. and head of pump can be improved by use of larger diam. impeller in same casing. As in most cases of rotary machines, higher speeds generally mean reduced costs of plant. Probably one of greatest advantages which centrifugal pump can offer is facilities for automatic control.—*H. E. Babbitt.*

Pumping Station Operation and Maintenance. C. KEEPING. Can. Engr.—Wtr. & Sew. **81**: 10: 18 (Oct. '43). Treatment of Winnipeg water supply, derived from Shoal Lake, consists chiefly of adding Cl_2 and NH_3, ratio being 5 : 1. Residual of 0.4 ppm. after 15 min. contact maintd. $CuSO_4$ used continuously during summer to discourage algae growths. Odors elimd. by adding activated C or by break-point chlorination. Water relatively soft and low in turbidity and color. McPhillips St. pumping station draws water from reservoir system contg. roughly 55 mil.gal. under suction head of almost zero and delivers to discharge header at 75 psi. Station contains 6 centrifugal pumps driven by elec. motors, 3 of variable speed type being used to adjust output to demand because no elevated storage. Pump impellers inspected after 6000 hr. operation (annual operating period of units carrying most of load), both pump and motor being cleaned and overhauled at same time. Records kept of all work done. Piping and valves inspected and flowmeter equip. cleaned and calibrated annually. Wire-to-water eff. tests made every 2 yr. Regular maint. avoids expensive repairs.—*R. E. Thompson.*

Efficient Diesel Pumping Station. WILL H. FULLERTON. Diesel Progress **9**: 12: 53 (Dec. '43). Water for New London, Conn., supplied by gravity from Lake Konomoc. Insufficient pressures in city required constr. of new pumping station. 4 Morris 10″ suction centrifugal pumps direct-connected to 85-bhp., 1200-rpm. Murphy diesels. Discharge to 3 preformed concrete standpipes of 1.5-mil.gal. capac. Feeders extend up 12′ into standpipes providing const. head on pumps to that level. Water for cooling jackets, mufflers and oil coolers taken from discharge main and returned to suction. Combined eff. over 75%; pump 85%; engines 90%. Fuel costs less than half cent per 1000 gal. with 120′.—*F. J. Maier.*

LABORATORY CONTROL—EQUIPMENT AND APPARATUS

The Suitability of Formaldehyde for Conserving Biological Samples. H. BETHGE. Kleine Mitteilungen (Ger.) **18**: 228 ('42). Comparison of samples showed that by addn. of formaldehyde 9.5% less plants and 31.6% less animals could be counted under microscope. Conservation caused difficulties in identification; form of organisms may be altered; colonies break apart. Concn. of 1–2% formaldehyde should be used.—*Willem Rudolfs.*

Titrimetric Determination of Lead With Potassium Chromate. R. FRICKE & R. SAMMET. Z. anal. Chem. (Ger.) **126**: 13 ('43). Method of titrating lead against potassium chromate described. When soln. contg. small amts. of lead ion mixed with very dil. soln. of 2,6-dichlorophenolindophenol, blue color of latter changes to violet. If then soln. of potassium chromate added drop by drop and mixt. shaken, turbidity due to colloidal matter develops; as more of reagent added color becomes more orange until at end point there is sharp change to green; at same time colloidal matter flocculated. By this method content of lead can be detd. to within 0.5 to 1.0% of true value. Certain ions, in amts. 10 to 20 times amt. of lead, cause end point to become uncertain.—*W.P.R.*

Conductometric Titration of Lead With Iodate. C. DRAGULESCU & E. LATIU. Z. anal. Chem. (Ger.) **126**: 63 ('43). Lead can be titrated against iodate conductometrically. Necessary to wait after each addn. of reagent until conductometric value const. because

basic lead iodate, which is at first formed, changes very slowly into normal salt.—*W.P.R.*

Potentiometric Titration of Lead With Iodate. C. DRAGULESCU & E. LATIU. Z. anal. Chem. (Ger.) **126**: 67 ('43). Potentiometric method of titrating lead against potassium iodate described. Excess of soln. of potassium iodate added to neutral soln. of lead nitrate and excess titrated against std. soln. of lead nitrate. Silver wire used as indicator electrode against normal calomel electrode in usual compensation app. Excess potassium iodate may also be titrated against std. soln. of silver nitrate.—*W.P.R.*

A Method of Determining Sulfate in the Presence of Interfering Cations. M. GOEHRING & I. DARGE. Z. anal. Chem. (Ger.) **125**: 180 ('43); Chem. Zentr. (Ger.) **1**: 2012 ('43). Method described for detn. of sulfate in presence of interfering cations. Soln. contg. sulfate made slightly acid with hydrochloric acid and filtered through synthetic-resin ion-exchange material, such as Wofatit KS, which removes ions of calcium, potassium, iron, aluminum and chromium. Ions of zinc and manganese, which do not interfere with detn. of sulfate, also removed. Portion of filtrate heated to boiling point and sulfate pptd. by addn. of soln. of barium chloride. Detn. of sulfate then carried out in usual way.—*W.P.R.*

A Simple Method for Preservation and Transmission of Samples of Water Required for Bacteriological Analysis. W. STEUER. Arch. Hyg. Bakt. (Ger.) **130**: 3/4: 138 ('43). Difficulties have arisen over rapid transmission of samples of water from Eastern Front. Samples, un-iced, and arriving at their destination several days after collection have little value for assessment of purity. Method described by which bacteria in water sample maintd. at their initial concn. so that examn. can be carried out several days after collection. Briefly, procedure consists of absorption of water on filter paper and storing in air-tight, water-tight cellophane envelopes. For total colony counts, filter paper about 10 cm. in diam. taken and one-quarter cut away. Paper then folded into cone and inoculated with ½–1 ml. of sample. Cone placed in sterile cellophane envelope and opening sealed with adhesive tape. For coliform count, larger filter papers and envelopes employed, so that as much as 10, 50 or even 100 ml. of water sample may be accommodated. Filter paper first placed in envelope, which has small openings at top and bottom. Water introduced by syringe or pipette through upper hole and allowed to flow on filter paper, where bacteria held up and excess water passes through and out of hole in bottom of envelope. Holes afterwards sealed with tape. Envelopes enclosed in grease-proof paper and packed in wooden box ready for transmission. Details given of filter paper and cellophane employed successfully in these operations. At lab. envelopes opened with sterile scissors and filter cones examd. One intended for total colony count opened out and placed in Petri dish and molten nutrient medium poured over it and thoroughly mixed. After incubation, colonies counted in quarter plate not obscured by filter paper. Filter cone intended for coliform count placed in tube of nutrient broth, incubated at 46° C. and then plated out on Endo medium. Usually several cones examd., each contg. different vol. of water; in highly pold. waters coliform count may be estd. by direct plating as for total colony count. Author investigated several possible sources of error liable to arise in this method. Contamn. might occur at points of sealing; adhesive tape investigated and found free from bacteria. Slight loss of bacteria might occur by contact with and in condensation water flowing onto cellophane, but this was not found sufficient to cause any appreciable loss of organisms. Actual alteration in numbers of bacteria on filter paper considered possibility, but shown that very little increase or decrease occurred. Some loss by bacteria percolating through paper and escaping in filtrate. Several expts. undertaken to test effy. of this preservation method. No significant change in total colony count on gelatine after filter cones inoculated and stored for as long as 12 days at temp. of 12–18° C. Pathogenic intestinal organisms survived on paper for 7 days and *Esch. coli* for 30 days. Paper sample stored in cellophane envelope compared with sample collected in usual glass bottle, latter being examd. at once; filter paper sample results same as bottle results up to 14 days after collection of sample. In addn., if bottle sample stored for few days at atm. temps., there was increase in counts, while results from filter paper samples remained const. at initial figures. (If this method found satisfactory, it might be useful in tropical countries where transport slow and use of ice impracticable.) —*B.H.*

A New Method for the Estimation of Micro Quantities of Cyanide and Thiocyanate. W. N. ALDRIDGE. Analyst (Br.) **69**: 262 ('44). Method described for detg. small amts. of cyanide and thiocyanate, which depends on conversion of cyanide and thiocyanate to cyanogen bromide, which then detd. by color produced on reaction with amine in pyridine soln. To 1 ml. of soln., contg. not more than 3 μg. of cyanide (as HCN) or 6 μg. of thiocyanate (as HCNS), which has been made acid with acetic or trichloracetic acid, are added 0.5 ml. of satd. bromine water and 0.5 ml. of 1.5% soln. of sodium arsenite. This mixt. may be left in stoppered bottle for 2 hr., after which 1 ml. of mixt. added to mixt. of 0.2 ml. of 2% aqueous soln. of benzidine hydrochloride and 5 ml. of pyridine reagent prepd. from 25 ml. of pure redistd. pyridine and 2 ml. of concd. hydrochloric acid, dild. with water to 100 ml. Orange color produced soon changes to red. After color allowed to develop for 10 min. at room temp., measured in photo-elec. colorimeter. If both cyanide and thiocyanate present in soln. to be analyzed, 2 detns. made: one on sample from which cyanide removed by bubbling air through soln. for 15 min. and second on untreated sample. Difference in values obtained with 2 samples gives amt. of cyanide present. Ferricyanides, cyanates, potassium and sodium phosphates, ammonium and sodium chlorides, potassium oxalate, sodium borate, cobalt acetate in small amts., phenyl acetic acid and ethyl alc. do not affect det. Org. cyanides and org. thiocyanates probably would affect detn. Method can be readily adapted to anal. of biol. material.—*W.P.R.*

Volumetric Benzidine Method of Determining Sulfates in Water and in Aqueous Extracts From Soil and Medicinal Mud. M. KONAREV. Gidrokhim. Mat., **12**: 103 ('41); Br. Chem. Physiol. Abstr. (Br.) C: 2 ('44). In method for volumetric detn. of sulfate in water and in aqueous extracts of soil and medicinal mud, sample, which contained 9–180 mg. of sulfate, pptd. with amt. of 0.075 *N* soln. of benzidine hydrochloride such that concn. of benzidine hydrochloride in filtrate 0.004 *N*. Alkali, in amt. equiv. to free hydrochloric acid in benzidine soln., added to filtrate which was then titrated with 0.05 *N* sodium hydroxide using phenolphthalein as indicator. Results showed that potassium, sodium and calcium ions did not affect reaction but that magnesium ions caused interference.—*W.P.R.*

A Field Method for Collection of Gases Dissolved in Natural and Borehole Waters. A. N. MURIN. Doklady Akad. Nauk S.S.S.R. (U.S.S.R.) **40**: 128 ('43); Compt. rend. acad. sci. U.R.S.S. (in English) **40**: 113 ('43). Simple, portable app. for removing gas from water samples consists of 2 flasks (6-l. and 2-l. capac.) connected by long rubber tube. Water sample first filled into 6-l. flask and then partly drawn off into 2-l. flask by evacuating latter with hand pump. Dissolved gas collects above water in 6-l. flask. Effectiveness of this method for exterminating gases from water illustrated by examples.—*C.A.*

Colorimetric Determination of Aluminum, Tin, Molybdenum and Chromium With Haematoxylin. V. J. TARTAKOVSKI. Zavodskaya Lab. (U.S.S.R.) **9**: 971 ('40); Br. Chem. Physiol. Abstr. (Br.) C: 8 ('44). Colorimetric detn. of aluminum with haematoxylin depends on formation, in dil. acetic acid, of stable, colored compd.; intensity of color increases as concn. of sodium or ammonium acetate in soln. increases. In procedure recommended, 50-ml. sample, contg. approx. 0.05 mg. of aluminum, first made neutral to phenolphthalein, then 1 ml. of *N* sodium hydroxide, 1 ml. of 1% soln. of haematoxylin, and 1 to 1.2 ml. of 30% soln. of acetic acid added; color thus obtained compared with std. Detn. cannot be carried out in presence of ferric ions. If free alkali or alkali carbonate present, neutralization must be effected with hydrochloric acid instead of acetic acid. Dichromate, molybdate and stannous ions also react with haematoxylin to form colored compds. which, however, stable in solns. more acid than those required for corresponding aluminum compd.; consequently chromium, molybdenum and tin may be detd. in presence of aluminum and ferric ions.—*W.P.R.*

Volumetric Zinc Uranyl Determination of Sodium [in Water] By the Method of Dobbins and Byrd. N. VESELOVSKI. Gidrokhim. Mat. **12**: 25 ('41); Br. Chem. Physiol. Abstr. (Br.) C: 39 ('44). In method of Dobbins and Byrd for volumetric detn. of sodium in water, soln. of zinc uranyl acetate added to water. Resulting ppt. of sodium zinc uranyl acetate dissolved in water and subsequently decomposed with 0.05 to 0.2 *N* soln. of sodium hydroxide to which 0.5% sodium chloride added to coagulate ppt. which is formed. Excess sodium hydroxide then titrated with hydrochloric acid using

phenolphthalein as indicator. Results obtained accurate to within 1% provided that amt. of sodium in sample greater than 4 mg. —*W.P.R.*

Microdetermination of Sulfate. A Colorimetric Estimation of the Benzidine Sulfate Precipitate. B. KLEIN. Ind. Eng. Chem.—Anal. Ed. **16**: 536 ('44). Simple, rapid, and accurate colorimetric method for detn. of small amts. of sulfate described. Sulfate in sample pptd. by soln. of benzidine hydrochloride. Benzidine sulfate, after purif., dissolved in 0.2 *N* hydrochloric acid; cooled soln. diazotized with 0.1% soln. of sodium nitrite, after which 0.5% ammonium sulfamate added to destroy excess nitrous acid. Soln. then coupled with *N*-(1-naphthyl) ethylenediamine dihydrochloride (Bratton and Marshall's reagent); intense purple color produced, intensity of which detd. by Klett-Summerson photo-elec. colorimeter. Control expt. with either std. soln. of sulfate or with one of benzidine hydrochloride should be carried out. Violet color obtained follows Beer's Law closely and stable; no decrease in intensity observed even after 12 hr. This method cannot be used for samples which contain chloride in such amts. that ratio by weight of chloride to sulfur greater than 30:1, since pptn. of benzidine sulfate under these conditions not complete; phosphates, in appreciable quants., also interfere and should be completely removed from samples. Method accurate for range from 0.05 to 0.150 mg. of sulfate per sample; max. error 2%.—*W.P.R.*

The Significance of Laboratory Examinations. A. E. BERRY. Eng. Cont. Rec. **56**: 14: 38 (Apr. 7, '43). Ont. Dept. of Health maintains 10 labs. for routine bact. examn. of water, 2 being equipped for chem. investigations of water and sewage. Sterile sample bottles provided in mailing cases and no limit to no. of samples which may be submitted. Samples examd. for presence of coliform bacteria only and water reported to sender as in class A, B, C or D, A representing no coliform bacteria in 50 ml. of sample. In Que., sample kit provided in which water sample added directly to culture media by collector.—*R. E. Thompson.*

DAM CONSTRUCTION AND MAINTENANCE

Penstocks Welded on High Dam. GILBERT L. YETTER. Western Constr. News **18**: 306 (July '43). Constr. of 5 penstock systems on northern Calif. dam much cheaper and stronger by welded joints rather than riveted ones. All joints tested by x-ray machines then subjected to high hydrostatic pressures.—*Ralph E. Noble.*

Application of Principles of Soil Mechanics to Rolled-Fill Earth Dams. D. F. GLYNN. Wtr. & Wtr. Eng. (Br.) **46**: 3, 62 (Jan., Feb. '43). Weight of earth and pressure of water most important forces. Sometimes dynamic forces due to percolating waters become significant. Shearing resistance of material important factor in stability of structure. Influence of pore pressure upon shearing resistance important. Compared with soil with moisture-filled pores, larger volumetric shrinkage occurs without development of dangerous pressures. Variables to be controlled during constr. to achieve desired condition of material: compactive effort, moisture content and density of soil. In location of materials and investigation of surface phenomena geol. mapping assisted by test pits and bores used to reveal subsurface phenomena. Identification and detn. of phys. properties of materials based upon lab. and field tests. Complexity of soil characteristics and variation of types within small areas have prevented use of few simplified tests. Visual examn. should include some type of x-ray or microscopic inspection. Permeability test both hardest to reproduce and most difficult from which to obtain accurate results. Coef. of permeability given by:

$$k = \frac{a}{A} \times \frac{L}{t} \log_e \frac{H_1}{H_2} = \frac{V}{At} \div \frac{H_1}{L}$$

in which k = coef. of permeability; a = area of water holder; A = area of soil specimen; L = length of specimen; t = time; H_1 and H_2 = initial and final heads of water and V = vol. of percolating water. Direct shear and cylindrical compression methods most used to measure shearing resistance. Difficult to measure pore pressure in direct shear

expt. and internal stress distr. complicated. In control and record groups, 4 main tests: moisture control, field density, movement of structure and pore pressure. Horizontal movements best detected by periodic surveys of std. signals set on fill. Safety of dam may be judged by comparing existing pore pressures with estd. pore pressures with estd. critical values and, if latter greater at every point, dam assumed to be safe. Problem of computing stability complicated by fact that solids exhibit plasticity as well as elasticity. Unique soln. required detn. of 9 stresses at any point, but statics provide only 6 equations. Present problem to find some criterion which will give 3 remaining equations. Constr. may be divided into prin. operations of excavation, hauling and spreading, conditioning, compaction and rock-fill slope protections. Development of borrow area first involves removal of top soil and vegetation. All loose and unsound rock must be removed from abutments and foundations before earth operations commence. Seeping foundation waters should not be allowed to sat. fill about to be rolled. Soil may be dumped in either lateral or horizontal heaps. Dumping and spreading under control of man responsible for spacing heaps. Thoroughness of previous conditioning largely dets. eff. of compaction. Possibly most important feature is to insure soil at correct moisture content. Factors to be observed if efficient compaction to be achieved: moisture content; top soil should be preserved as loose as possible; thickness of layer should not exceed about 2″ less than length of tamping foot; rollers must be kept fully ballasted and cleaned; correct no. of passes over all portions of area; and feet should not be used when worn. Field control must be preserved to insure routine carried out thoroughly. In most U.S. Bur. of Reclamation dams customary to provide rock-fill sections at both faces. In both math. anal. and in selection and zoning of materials, design must give consideration to effect of pore pressure on stability of structure and to prevent undesirable seepage.—*H. E. Babbitt.*

Design of Samson Brook Dam, Western Australia. RUSSELL J. DUMAS & ROBERT A. MACBETH. Civ. Eng. (Br.) **37:** 143 (July '42). Dam situated 8 mi. southeast of Waroona, town 70 mi. from Perth. Dam completed May '41 in narrow gorge in heavily timbered country. Basin formed will cover 250 acres, and capac. at spillway level will be 1.777 billion gal. (Imp.). Earthen embankment divided into 7 zones: (1) upstream rock facing including gravel backing; (2) unselected material between 1.5 : 1 slope and pug core; (3) selected material between 1.5 : 1 slope and pug core; (4) pug core; (5) selected material between pug core and 1 : 1 slopes downstream; (6) unselected material between 1 : 1 and 1 : 6 slopes downstream; (7) rock-fill between 1.6 : 1 and 2 : 1 slopes downstream. Zones of selected material and pug core relatively impermeable sectors of embankment. Drainage system provided at junction between downstream selected and unselected materials. Circumstances compelled constr. of take-off beneath bank, contrary to author's opinion that this not good practice. After some exptg., hydr. jump designed to consume energy of discharge. Design gives strongly defined jump at all flows when water cushion fills. Position of jump practically unchanged at all flows. After overflowing crest of weir water will pour down funnel-shaped shaft reduced to diam. of 10′, at approx. depth of 40′, which dimension is retained until it junctions at depth of 65′6″ by means of short bend with outlet tunnel of same diam. Approx. 211,000 cu.yd. of earth-fill in embankment and 6000 cu.yd. concrete in core.—*H. E. Babbitt.*

Alaska's Largest Hydraulic Fill Dam. CHET BRYANT. Pac. Bldr. & Engr. **48:** 5: 39 (May '42). Largest dam of type in Alaska; constr. watched with interest as expt. worthy of cost if successful; as risk until proved sound. Located at Livengood, 82 mi. northwest of Fairbanks. Completed dam will be 1600′ long, 65′ above creek level, 300′ wide at base, 22′ at crest. Upstream face open on 2.3 : 1 slope; downstream, 2 : 1. Fill will contain approx. 450,000 cu.yd.; 48″ bypass pipe through dam bottom with control valve operated from downstream face, and spillway near left side, to handle any impounded surplus water, although spring runoff and heavy summer rains not expected to exceed capac. of tunnel and ditch to Livengood Cr. By Sept. '41, fill consisted of slimy, smelly, easily-packed, decomposing vegetative soil when wet.—*Ralph E. Noble.*